"L'énorme et vieux ventilateur brassait l'air lourd d'odeurs… Macao, Macao, Macao 6 plombes du mat"

Bloody hell, an helo on a stick ! worth than 9/11

INGENIERIE

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contact@airflex-ingenierie.fr

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15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

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Subjects of the Month: Bloody hell, an helo on a stick !

How to Create More Environmentally Sustainable Aviation

The Air Up There Podcast – Reducing Aviation Noise and Emissions (faa.gov)

Climate change impacts the world we live in today as well as future generations. As with other transportation sectors, aviation plays a role in sustainability. The Federal Aviation Administration (FAA) rolls out Phase III of its Continuous Lower Energy Emissions and Noise (CLEEN) Program, working with stakeholders to decrease aviation's effects on climate change. Among other things, Phase III of the CLEEN Program introduces new environmental goals to reduce aviation emissions and noise, including CO2 emissions.

Listen to the episode on FAA.gov, Apple Podcasts, Stitcher, or Google Podcasts!

We sat down with Kevin Welsh, FAA's Executive Director of the Office of Environment & Energy, and David Hyde, former Director of Environmental Policy at the Aerospace Industries Association, to discuss what CLEEN is, what success looks like, and what's exciting about this new phase.

Accidents causés par des éoliennes

98 bris de pales de 1992 à 2006

Un site en anglais a des informations vérifiées sur les éoliennes. http://www.wind-watch.org/

Ces informations sont maintenant complétées par des sites anglais.

En particulier, le site tient une liste des accidents documentés dans la presse ou des rapports de police dans le monde.

http://www.wind-watch.org/documents/wp-content/uploads/accidents-1nov2006.xls

http://www.wind-watch.org/documents/wp-content/uploads/accidentsummary-1nov2006.doc

D'autres sites suivent les accidents et les problèmes que les assurances, telles qu'Allianz, doivent couvrir. Des articles signalent que le taux d'accidents sérieux augmente et qu'il y a des défauts graves dans les éoliennes modernes allemandes qui n'ont pas été suffisamment testées. Les Américains installent enfin des centres de tests pour vérifier la technologie avant installation.

Pour empêcher les accidents de personnes, une précaution minimale est que les pales soient testées dans des laboratoires comme on le fait pour les ailes d'avion et que des prototypes soient installés loin des maisons avant que ces modèles ainsi testés pendant de longues périodes soient déployés en zones habitées. Du fait de l'oubli de cette précaution industrielle élémentaire, les constructeurs sont en retard pour produire des machines raisonnablement sûres et les délais pour la livraison ou pour fournir les pièces de rechange après accident ou révision s'étendent de plusieurs mois à deux années. Le périodique "Der Spiegel" suit ces problèmes et traduit quelques uns de ses articles en anglais. Les dangers de l'éolien Sommaire d'articles sur l'éolien et le climat.

Il est interdit de s'approcher de certains parcs d'éoliennes. Par exemple, par temps de gel, il faut rester à plus de 300 m des petites éoliennes car de gros blocs de glace peuvent se détacher des pales et atterrir à cette distance. Il faudrait rester à plus d'un km des turbines géantes.

Par temps de tempête, on ne se promène pas dans les bois et il ne faut pas non plus s'approcher des éoliennes car des pales brisées ou des mats qui s'écroulent peuvent atterrir à plusieurs centaines de mètres (photos sur [36]) mais on ne peut pas déplacer sa maison par grand vent. On ne peut pas construire d'éoliennes qui pourraient tomber sur des routes de grande circulation.

310 accidents sont signalés.

Le plus fréquent est le bris de pales. 98 éoliennes ont eu une ou plusieurs pales brisées de 1992 à septembre 2006. Celles-ci sont projetées, parfois au delà de 400 m, par des éoliennes plus petites que celles qu'on propose aujourd'hui. On est maintenant (mai 2010) à 172 bris et une projection jusqu'à 1300 m en Norvège.

La distance maximum des jets observés, aussi bien pour des débris de pales que des projections de glaçons est actuellement de 500 m depuis la base de la tour. Une personne au bas de la tour a été sérieusement blessée en recevant un glaçon provenant de haut (en 2000). Des jets de glaçons sont souvent confondus avec des coups de feu. Depuis des éoliennes avec pales chauffées sont requises en zones exposées.

Il n'y a presque pas d'accidents au Danemark et en Hollande mais cela serait dû à ce que la presse n'en parle pas. L'industrie éolienne n'est pas tenue à déclarer ses accidents et incidents comme cela se fait dans les autres industries. Ceux qui comptabilisent les accidents sur le site cité pensent que les accidents répercutés dans la presse ne représentent que le sommet de l'iceberg. Ce sont des bénévoles qui font ce comptage pour compenser les déficiences graves des services officiels. Les sites allemands sont mieux documentés.

Les éoliennes modernes ont autant d'accidents. L'accident n° 396 du 9 mars 2006 entre les villages de Alsdorf et Boscheln (Übach-Palenberg) concerne un bris de pales sur une turbine Nordex N90 de 2,3 MW, avec un mat de 100 m et une hélice de 90 m de diamètre, donnant une hauteur totale de 145 m.

Quel est le risque à La Roche? 100 bris de pales pour 30.000 éoliennes dans le monde donne un risque de 1/300 par éolienne ou de 1/50 pour 6 éoliennes. Comme les données statistiques sont collectées sur des éoliennes ayant servi peu de temps (disons 5 ans) au lieu d'une durée de vie attendue de 15 ans, il faut multiplier par 3. Le risque qu'il y ait un bris de pales pendant la vie d'un parc éolien comme La Roche est donc de 3/50 ou 6% mais les chances peuvent être bien supérieures puisque le domaine est en évolution et les statistiques ne sont pas complètes. Des assureurs (Allianz) estiment qu'ils doivent indemniser une moyenne d'un accident tous les 4 ans par contrat. Jusqu'ici, les bris de pales n'ont pas causé de blessures humaines. Le fait que les héritiers seront indemnisés n'est pas très tranquillisant pour ceux qui doivent vivre à proximité d'une éolienne. Plutôt que d'ignorer ce risque, il est sage de réduire le danger physique d'un

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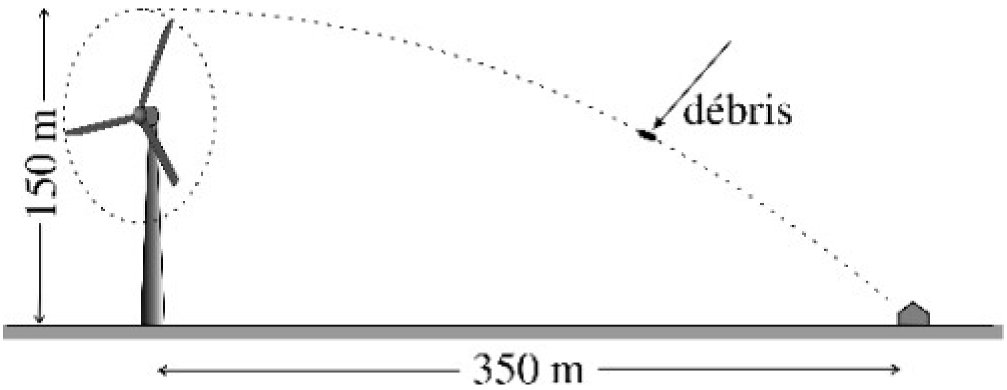
15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

accident en construisant les éoliennes à une distance suffisante des habitations. Cela réduirait aussi des dangers plus fréquents : jets de glaçons et troubles du sommeil.

Distance minimum de sécurité

« Les prescriptions en vigueur au Luxembourg prévoient qu'à la limite des zones résidentielles existantes, la pression sonore causée par les éoliennes ne peut, dans des conditions de référence, dépasser 35 dB(A). Cette limite de bruit est faible comparée à celle qui est en vigueur dans d'autres pays. Cette obligation technique garantit des distances plus importantes entre les éoliennes et les zones résidentielles. Selon le comportement sonore du type d'éolienne et la configuration du parc, ces distances peuvent se situer entre 600 et 1200 mètres ».



Feu au sommet du mat

L'autre accident fréquent est le feu dans la nacelle (44 accidents). Le feu (1000 litres d'huile de graissage en feu) est trop haut pour être combattu. Il envoie des débris enflammés pendant plus d'une journée.

- 37 cas de tour s'écroulant ou de dommage majeurs à la structure. Les dégâts sont limités à 150 m.
- Accidents mortels lors de la construction et la maintenance
- 37 accidents mortels, 31 étant des ouvriers tombés de la tour pendant le montage ou l'entretien. Cela rend cette industrie une des plus dangereuses par unité d'énergie produite (par TWh).
- 3 accidents mortels de circulation sont attribués par la police à des conducteurs distraits par la vue d'un parc d'éoliennes. D'autres accidents concernent un parachutiste tombant sur une éolienne et un ULM pris dans un rotor. Un avion a percuté une éolienne (peut-être s'agissait-il d'un suicide).

Des petites éoliennes (45 m de diamètre) construites par la Tennessee Valley authority sont entourées d'un cercle de barrières jaunes à plus de 100 m et de panneaux "No Trespassing". (Page 4-18, Fig. 4-9). Des caméras sont installées pour surveiller le site (en 2003).

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Problèmes de santé

Des médecins signalent que des sons graves (le battement sourd typique des éoliennes) se propagent assez loin et passent à travers des fenêtres fermées et des cheminées [124]. Des personnes ont leur sommeil compromis par ce bruit jusqu'à plus d'un mile (1 ,6 km).

La plupart des gens qui vivent depuis quelque temps près d'éoliennes signalent qu'ils souffrent de cette proximité. Cela est d'autant plus difficile à supporter quand ils s'aperçoivent que ces éoliennes qui salopent leur environnement naturel n'ont pas d'effet sensible sur le climat mais sont le résultat d'un affairisme de grande envergure.

Les petits arrangements avec la vérité de Sortir du Nucléaire». La tribune de Bernard Durand

« Dans le monde, peu de pays peuvent se targuer d'émettre aussi peu de gaz à effet de serre (GES) que le nôtre en matière de production d'électricité »

Les intentions du réseau d'associations Sortir du nucléaire sont claires, contenues dans son nom. Ce qui l'est moins, en revanche, ce sont les méthodes employées par cette nébuleuse proche de Greenpeace pour obtenir gain de cause. Pour inciter l'opinion et les pouvoirs publics à épouser ses vues anti-nucléaire, le réseau n'hésite pas à s'autoriser quelques arrangements avec la vérité : manipulation (voire escamotage) de chiffres, trucages, mauvaise foi, tout est bon pour tenter de convaincre. En témoigne la plainte qu'il vient d'adresser à Orano pour « publicité mensongère », plainte assortie de nombreuses contre-vérités.

En France, le nucléaire a bien le cycle de vie le moins émetteur. Citée dans un article de Reporterre évoquant cette plainte, Marie Frachisse, juriste pour le réseau, affirme ainsi : « Effectivement, un réacteur nucléaire émet moins qu'une centrale à charbon. Mais, si l'on prend l'ensemble de la chaîne de production de l'énergie nucléaire de l'extraction minière à la gestion des déchets, ce bilan est beaucoup plus lourd. » Une affirmation très contestable.

Le GIEC, pourtant peu suspectable de faire le jeu du lobby nucléaire, a calculé les émissions des différentes sources d'électricité. Il s'agit d'analyses du cycle de vie (ACV), dites aussi du berceau à la tombe (cradle to grave en anglais). C'est-à-dire qu'elles intègrent pour le nucléaire toutes les émissions collatérales comme celles de l'usine de Malvesi citée par Madame Frachisse, ainsi que de l'extraction des minerais et des stockages de déchets.

La moyenne mondiale de ces émissions (ACV), selon le GIEC, est pour l'électricité nucléaire de 12 gCO2eq./kWh produit. Pour la France, elles se situent en dessous de la moyenne mondiale, 6 g/kWh, comme l'a enfin reconnu, de très mauvaise grâce d'ailleurs, le Ministère de la transition énergétique et solidaire, et même l'ADEME ! Elles sont même probablement seulement de 4 g/kWh, parce que la France utilise maintenant l'ultracentrifugation pour enrichir l'uranium et ainsi produire le « combustible » des réacteurs nucléaires. Or cette méthode consomme 50 fois moins d'énergie que ne faisait la méthode par diffusion gazeuse utilisée auparavant.

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Le remplacement en France d'une production d'électricité nucléaire par une production d'électricité éolienne ne peut absolument rien pour le climat

En comparaison, l'éolien, que promeut sans relâche entre autres Greenpeace (certains disent que c'est parce qu'elle a une filiale Greenpeace Energy très liée aux industries éoliennes (1) ; c'est peut-être une fake news, mais qu'attend Greenpeace pour démentir ?), mais aussi WWF et FNE (toutes trois prétendant être des défenseurs de l'environnement et en particulier du climat), émet en ACV en France 11 gCO2eq./kWh selon le Ministère ! Mais aussi, l'éolien est, au prorata de sa consommation de terres rares importées de Chine pour fabriquer les aimants permanents de ses génératrices d'électricité, responsable du désastre écologique et sanitaire provoqué en Chine par l'extraction et le raffinage de ces terres rares (2).

Le remplacement en France d'une production d'électricité nucléaire par une production d'électricité éolienne (c'est ce que veulent Greenpeace, WWF et FNE, mais aussi on se demande bien pourquoi notre Gouvernement), ne peut donc absolument rien pour le climat, contrairement à ce qu'affirme par exemple avec constance Yannick Jadot, qui a été Directeur de la branche française de Greenpeace. C'est encore pire avec le solaire photovoltaïque, dont les émissions seraient de 40 à 50 g/kWh !

Du fait de leur intermittence, et de l'absence actuelle et pour longtemps de solutions pour réaliser des stockages massifs d'électricité à l'échelle des énormes quantités produites en France et en Europe, l'éolien et le solaire photovoltaïque ont besoin en soutien d'une très importante puissance de centrales pilotables, nucléaires et hydrauliques en France, à charbon et à gaz en Allemagne. Une démonstration éclatante en est fournie par l'Allemagne, dont la puissance de pilotables est passée de 100 à 102 GW entre 2000 et 2019, tandis que la puissance d'éolien et de solaire photovoltaïque est passée de 7 à 102 GW. Si bien que l'Allemagne a maintenant plus de deux fois plus de puissance électrique installée qu'en 2000. Deux réseaux de centrales donc pour produire au total à peu près la même quantité d'électricité, c'est la principale raison de l'augmentation du prix de l'électricité pour les ménages dans ce pays (maintenant presque le double du nôtre). Et les mêmes causes produisant les mêmes effets cela est en train de se produire maintenant en France !

Notons au passage que si nous sommes capables un jour de construire des stockages massifs pour remplacer les centrales pilotables, leur coût sera probablement supérieur à celui de celles-ci.

D'autre part, comme les Allemands qui ont conservé leurs centrales à charbon et entreprennent maintenant de les remplacer par des centrales à gaz alimentées par du gaz russe, nous sommes obligés pour pallier l'intermittence de l'éolien et du solaire photovoltaïque de conserver toute notre puissance de réacteurs nucléaires. Nous pourrions bien sûr également les remplacer par des centrales à gaz russe, mais certainement pas par de l'éolien et du solaire PV ! Au nom de la défense du climat ?

L'illusion du tout renouvelable. De son côté, Mycle Schneider, consultant indépendant sur l'énergie et le nucléaire cité dans le même article de Reporterre, affirme qu'un euro dépensé pour les électricités renouvelables remplace un euro dépensé pour l'électricité nucléaire. C'est parfaitement faux : en fait il s'ajoute à celui dépensé pour le charbon et le gaz en Allemagne, comme je l'ai montré ci-dessus, d'où l'augmentation rapide dans ce pays du prix de l'électricité pour les ménages, ainsi que du nombre de ces ménages en précarité énergétique. En France, il s'ajoutera à celui dépensé pour le nucléaire. Et si en Allemagne il diminuera les émissions de CO2 de la production d'électricité, mais peu comme tout le monde peut le constater, il sera totalement inefficace en France, où il remplacera une production d'électricité nucléaire non émettrice et ne diminuera aucunement les émissions de CO2 de notre production d'électricité.

En France, une éolienne produit en moyenne dans l'année 3 à 4 fois moins d'électricité qu'un réacteur nucléaire par unité de puissance installée. Pour remplacer la production de l'EPR de Flamanville, de puissance 1 650 MW, il faudrait donc installer 5 000 à 6 000 MW d'éoliennes, et ainsi coloniser un territoire de 1000 à 1500 km2 en y comptant les distances de protection des habitations (qui vont peut-être d'ailleurs augmenter suite aux plaintes de plus en plus audibles des riverains), au lieu de 1 km2 pour Flamanville.

Dans le monde, peu de pays peuvent se targuer d'émettre aussi peu de gaz à effet de serre (GES) que le nôtre en matière de production d'électricité. Ce sont tous des pays qui ont des ressources très importantes en hydroélectricité par habitant

Compte tenu des recours de plus en plus nombreux des habitants, je pense que le temps nécessaire pour installer ces éoliennes sera du même ordre de grandeur que pour l'EPR ! Et tout cela pour produire une électricité dont nous n'avons pas besoin, car notre consommation n'augmente plus, et qui ne peut rien, ni pour le climat, ni pour fermer des réacteurs nucléaires. Pousser dans notre pays au développement massif de l'éolien et du solaire photovoltaïque, c'est de la schizophrénie pour qui prétend défendre le climat, comme Sortir du nucléaire, Wise, Greenpeace, WWF et FEN, et c'est un très gros mensonge qui ne peut tenir que grâce à la désinformation incessante des Français par les médias à ce sujet.

Dans le monde, peu de pays peuvent se targuer d'émettre aussi peu de gaz à effet de serre (GES) que le nôtre en matière de production d'électricité. Ce sont tous des pays qui ont des ressources très importantes en hydroélectricité par habitant : Autriche, Brésil, Costa-Rica, Norvège, ou qui la complètent avec du nucléaire : Suède, Suisse. C'est bien sûr parce que ce mix, qui est aussi le nôtre, évite très largement l'utilisation de combustibles fossiles. Ce qui n'est pas le cas de ceux aux faibles ressources hydroélectriques, qui comme l'Allemagne développent l'éolien et le solaire et refusent le nucléaire, parce qu'ils ont besoin en soutien de centrales à combustibles fossiles. Sortir du Nucléaire, Wise, Greenpeace, WWF, FNE ont poussé constamment au développement de l'éolien et du photovoltaïque plutôt qu'à celui du nucléaire. Ils poussent donc en fait à une addiction aux combustibles fossiles, comme en Allemagne, et ont donc une énorme responsabilité dans la dérive climatique observée actuellement. Si l'Allemagne avait développé son nucléaire pour supprimer son charbon et son gaz, elle aurait maintenant comme la France de faibles émissions de CO2 de son électricité, et une électricité beaucoup moins chère.

Quant à la diminution chez nous des émissions de CO2 dues au secteur électrique, elle a commencé dès la mise en service des premières centrales nucléaires ayant remplacé les centrales à fuel. Sans cette diminution considérable antérieure pour une large part à 1990, la France aurait actuellement des émissions de CO2 de la production électrique comparables à celles des énormes émissions de l'Allemagne.

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Notons pour finir que la France a signé la Convention d'Aarhus, qui exige une information factuelle et honnête des citoyens sur ce type de sujet. Est-ce bien le cas de nos médias et de notre gouvernement ?

(1) : Fabien Bouglé, 2019 : Eoliennes, la face noire de la transition écologique. Editions du Rocher.

(2) : Guillaume Pitron : La face cachée de la transition énergétique et numérique, la guerre des métaux rares. Editions Les Liens Qui Libèrent.

Bernard Durand a été directeur de la Division Géologie-Géochimie de l'Institut français du pétrole et des énergies nouvelles (IFPEN), puis de l'Ecole nationale supérieure de géologie. Il a aussi présidé le Comité scientifique de l'European Association of Geoscientists and Engineers (EAGE). Il est cofondateur de l'association environnementale «Nature en Pays d'Arvert». Prix Alfred-Wegener de l'EAGE.

Rapport du GIEC : le CO2 et les autres

Eclairage signé Christian de Perthuis, professeur d'université

Le blog de Christian de Perthuis, c'est ici : https://christiandeperthuis.fr/blog/

Les émissions de CO2 sont la cause principale du réchauffement global. Pour bien cerner leurs impacts climatiques, il convient d'analyser leurs interactions avec les autres rejets humains dans l'atmosphère. Le rapport du WG1 (« Working group 1 ») du GIEC apporte une information précieuse en la matière. Les décideurs sauront-ils l'utiliser ?

Des rejets qui réchauffent et d'autres qui refroidissent la planète

Comme l'a rappelé le précédent article, le réchauffement global depuis l'ère préindustrielle est estimé à 1,1°C par le WG1. Si on cumule la contribution de l'ensemble des gaz à effet de serre présents dans l'atmosphère (en bleu sur le graphique du dessus), on trouve pourtant un réchauffement de 1,5°C. Le GIEC aurait-il fait une erreur de calcul ?

Si c'était le cas, cela se saurait. Les rapports d'évaluation sont scrutés à la loupe par des observateurs pas toujours bien intentionnés. La réalité est que d'autres rejets humains dans l'atmosphère ont contribué à refroidir le climat de 0,4°C. En retranchant ces 0,4 de la contribution de 1,5°C des gaz à effet de serre, on retrouve bien un réchauffement de 1,1°C.

Notre graphique introductif permet de repérer les principales substances dont les rejets dans l'atmosphère affectent le système climatique :

Parmi les gaz à effet de serre : le CO2 a contribué à un peu plus de la moitié du réchauffement (53%) et le méthane à son tiers (34%). Le protoxyde d'azote et les gaz fluorés ont ensemble compté pour 13% ;

Les composants organiques volatiles (COV) et le CO sont des substances toxiques, mais ne sont pas à effet de serre. En plus de leurs effets délétères, ils contribuent à fabriquer de l'ozone qui, lui, est à effet de serre et réchauffe la planète. Ils sont des « précurseurs » de gaz à effet de serre. Leur élimination est souhaitable tant pour réduire les pollutions locales que pour lutter contre le changement climatique ;

Les NOx et les aérosols principalement rejetés lors de la combustion d'énergie sont également nocifs. Ils exercent par contre un effet de refroidissement sur la planète. Les NOx détruisent du méthane. Les aérosols qui sont des particules solides freinent le rayonnement solaire (à l'exception notable des suies ou « black carbone »). Leur élimination, souhaitable sous l'angle sanitaire, pose la question du lien entre l'action climatique et la lutte contre les pollutions locales.

Lutte contre les pollutions locales et action climatique

Dans la majorité de cas, les polluants locaux sont rejetés en même temps que le CO2 lors de la combustion d'énergie fossile. Par exemple une centrale électrique à charbon ou un moteur diesel rejettent du CO2, mais aussi du SO2 (principale source d'aérosols), des NOx et d'autres microparticules qui sont des polluants locaux.

Contrairement au CO2, ces polluants ne séjournent que quelques jours dans l'atmosphère. Agir sur les émissions de CO2 en réduisant la combustion d'énergie fossile apporte dès lors un co-bénéfice environnemental immédiat via leur élimination. On est dans une logique gagnant-gagnant.

Simplement, le gain futur sur le réchauffement est affaibli par le moindre refroidissement lorsqu'il s'agit de NOx, de SO2 ou d'autres aérosols (à l'exception du « black carbon ») qui refroidissent la planète.

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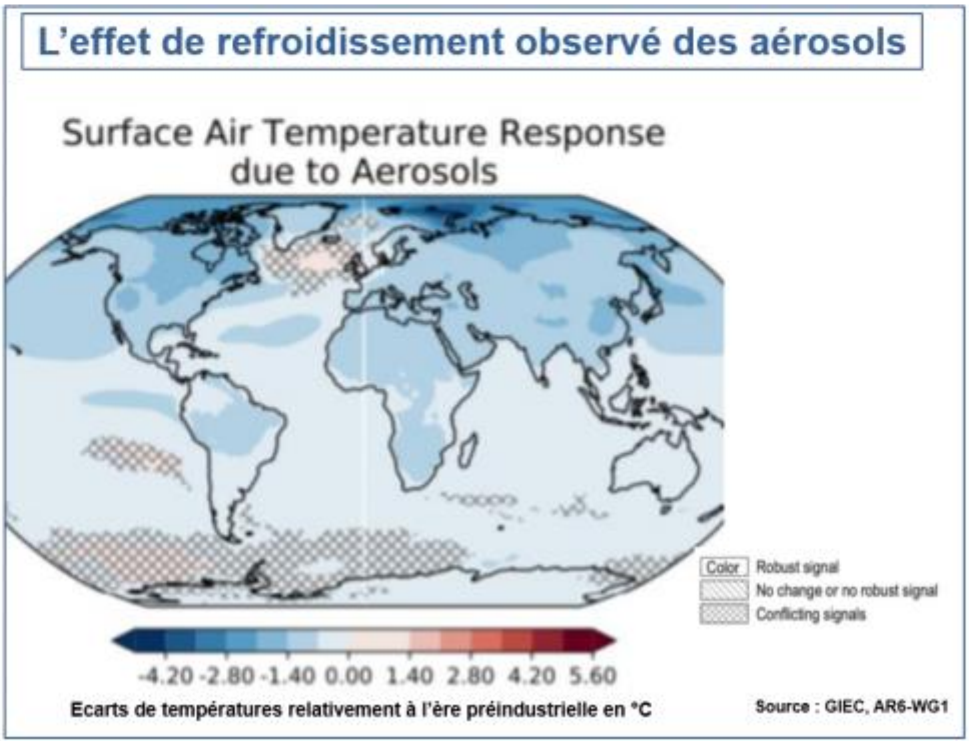
Les décideurs politiques cherchent les résultats immédiats (et visibles). C'est pourquoi de nombreuses régulations ont été introduites pour réduire les polluants locaux associés à l'usage des énergies fossiles.

Dans ces cas, on lutte bien contre les pollutions locales, mais on contribue à réchauffer la planète par moindre effet de refroidissement des aérosols ou des NOx. Si on continue sur cette voie, notamment en Asie où est désormais concentrée la grande majorité des rejets d'aérosols, ou pour la navigation maritime, on risque d'accélérer le réchauffement en réduisant les effets de refroidissement des aérosols et des NOx sans réduire le CO2.



Un effet de refroidissement global un peu supérieur à 0,5 °C

Le cas de la biomasse est particulier. Sa combustion rejette du CO2 biogénique qui a été préalablement stocké dans la plante. Elle est considérée comme neutre si on renouvelle le stock.

La substitution d'une énergie fossile par de la biomasse est donc bénéfique pour le climat. Mais la combustion de la biomasse génère des substances nocives. Dans le monde, elle est la première source de décès par la pollution de l'air du fait de son usage dans les systèmes de cuisson dans les pays moins avancés.

Si on remplace ces systèmes traditionnels par du butane ou du gaz naturel (voie généralement privilégiée) on réduit les dégâts de la pollution locale mais on contribue au réchauffement global.

Pour s'inscrire dans les trajectoires bas carbone décrites dans les scénarios du GIEC, il convient d'assurer une bonne convergence entre action climatique et lutte contre les pollutions locales. Une autre condition est d'agir vite sur les émissions de méthane.

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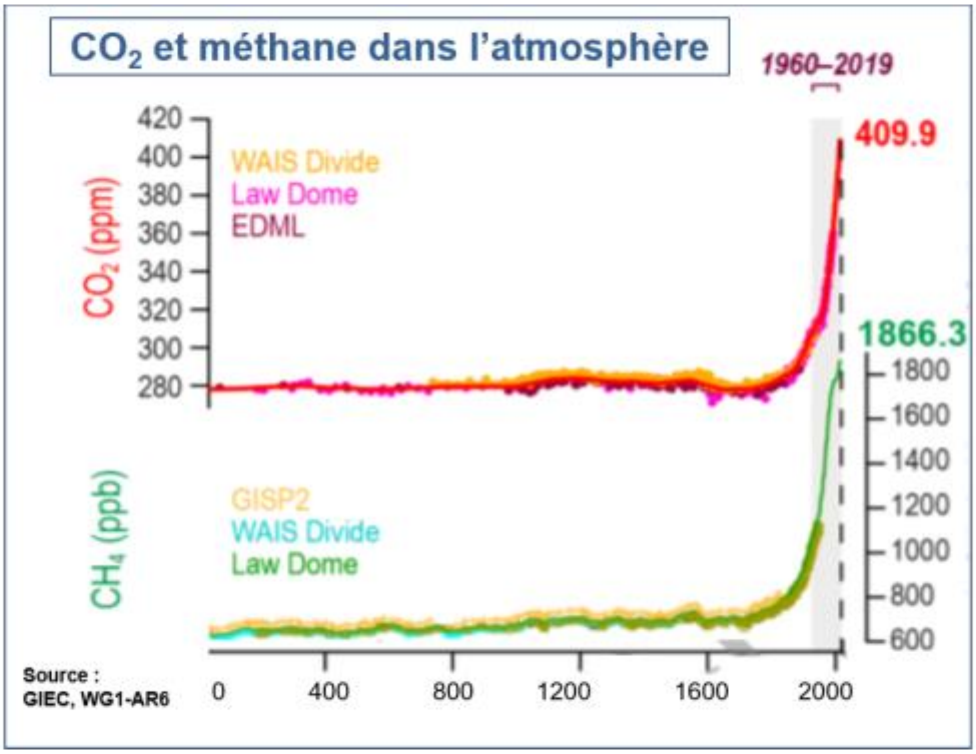
15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

La réduction des rejets de méthane : un enjeu crucial

Le méthane stocké dans l'atmosphère à la suite des rejets humains exerce un effet de réchauffement un peu supérieur à 0,5°C. Cela équivaut à deux-tiers de l'impact du stock de CO2, ou encore à l'effet de refroidissement de l'ensemble des aérosols. Cela est du à l'augmentation de sa concentration par rapport à l'ère préindustrielle qui n'a rien à envier à celle du CO2.



Contrairement au CO2, le méthane rejeté par les activités humaines ne séjourne pas très longtemps dans l'atmosphère : 12 ans en moyenne. Un coup de frein à ses émissions aurait donc un impact rapide sur le stock et pourrait contrebalancer l'effet de réchauffement associé à l'élimination des aérosols. C'est pourquoi la baisse rapide des émissions de méthane est une condition incontournable de réalisation des scénarios bas carbone décrits par le WG1.

L'action sur les autres gaz à effet de serre compte également, mais dans des proportions moindres. Leurs contributions respectives au réchauffement ne sont que de l'ordre de 0,1°C.

Les rejets de gaz fluorés, principalement utilisés pour la climatisation, sont désormais entièrement encadrés par les règles du protocole de Montréal (1987). Ce protocole a déjà fait le travail pour éliminer les rejets des gaz CFC à pouvoir de réchauffement très élevé. Comme ces gaz restent environ 50 ans dans l'atmosphère, les résultats de cette action réussie ne vont pleinement apparaître que durant les prochaines décennies.

L'action sur les rejets humains de protoxyde d'azote ne produira pleinement ses effets sur le climat qu'avec des délais encore plus longs. Une fois rejeté dans l'atmosphère, ce gaz y séjourne un peu plus d'un siècle. Comme dans le cas du méthane, la principale source de rejet de protoxyde d'azote est l'agriculture.

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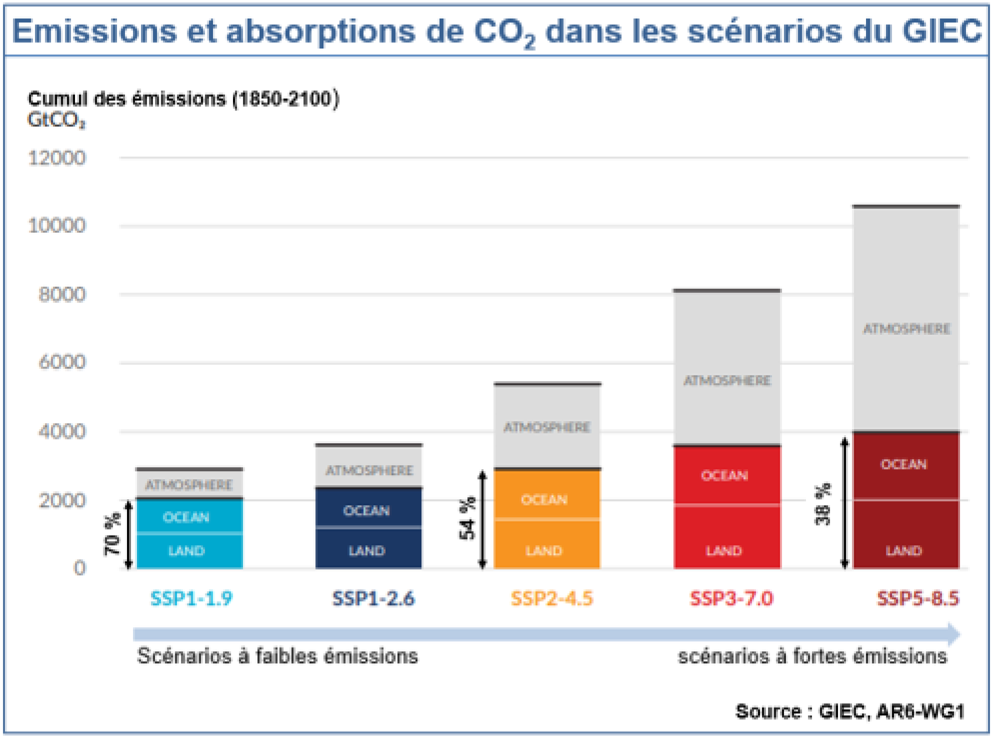
Le CO2 et son absorption par les puits de carbone

Contrairement aux autres gaz à effet de serre, le CO2 n'a pas une durée de séjour moyenne fixe dans l'atmosphère. La quantité de CO2 qui quitte l'atmosphère est conditionnée par son absorption par les réservoirs naturels dénommés « puits ». Sur terre, le CO2 est piégé par les plantes via la photosynthèse. Sur mer, il se dissout en surface et se transforme chimiquement via les algues. Actuellement, l'action combinée du puits de carbone terrestre et des océans absorbe un peu plus de la moitié des rejets anthropiques de CO2 (31% pour les continents et 23% pour les océans), le reste s'accumulant dans l'atmosphère.

Le WG1 n'a pas détecté de variation claire de cette proportion durant les dernières décennies. Il alerte cependant sur la probable perte d'efficacité des puits de carbone durant les prochaines décennies à la suite du réchauffement. De ce fait, la proportion du CO2 absorbée par les puits naturels devrait fortement baisser dans les scénarios fortement émissifs (graphique).



Pour limiter la perte d'efficacité future des puits de carbone naturel, la voie la plus sûre est d'accélérer la réduction immédiate des rejets de gaz à effet de serre et de mieux protéger la nature.

Une voie complémentaire consiste à renforcer la capacité d'absorption naturelle de CO2 par des techniques consistant à éliminer directement le CO2 de l'atmosphère ou à accroître la capacité des plantes ou de l'océan à l'absorber.

Le WG1 mentionne l'existence de ces techniques qui s'apparentent à la géo-ingénierie, sans se prononcer sur leur potentiel. Ce sera le rôle du WG3 sur l'atténuation du réchauffement d'étudier les conditions de leur déploiement.

Le rôle du WG1 n'est pas de se pencher sur les solutions à mettre en œuvre face au réchauffement, mais à mettre entre les mains des décideurs les bases scientifiques permettant de guider l'action. Sous cet angle, la prise en compte des multiples interactions entre le CO2, les autres gaz à effet de serre et les pollutions locales est un prérequis pour accélérer l'action face au réchauffement.

Un autre apport précieux du WG1 est de faire le point sur les caractéristiques d'un système climatique bousculé par l'accumulation de nos rejets de gaz à effet de serre. Ce sera l'objet du prochain article : « Le climat dans tous ses états« .

Tous les chiffres utilisés dans cet article sont issus du rapport du WG1.Les originaux des graphiques 1 et 4 se trouvent dans le « Résumé pour décideurs » (P.8 et P.27), celui du graphique 2 dans lechapitre VI(P.142) et et celui du graphique 3 dans le « Résumé technique » (P.142).

Le démantèlement et le recyclage des éoliennes

La durée de vie d'une éolienne est de 20 à 30 ans. Mais depuis quelques temps d'anciens parcs sont démantelés avant d'atteindre cet âge. La technologie dans ce domaine ayant fort évolué, le remplacement d'anciennes machines par des éoliennes plus puissantes et plus productives est rentable et permet aussi de produire plus d'énergie renouvelable. Mais que fait-on alors des éoliennes démantelées ? Leur recyclage est-il possible ?

C’est à Ulfborg au Danemark qu’a été construite en 1975 la première grande éolienne européenne munie de pales en fibre de verre. D’une puissance de 0,9 MW, elle tourne toujours aujourd’hui et produit de l’électricité pour le centre scolaire de Tvind. Mais c’est dans les années ’80 et ’90 que les parcs éoliens ont commencé à se multiplier sur notre continent. Aujourd’hui, après plus de 20 ans de bons services, ces machines sont démantelées pour être le plus souvent remplacées par des éoliennes plus puissantes. En France, on estime à 1.500 le nombre de turbines à démonter dans les cinq ans à venir. Or, la Programmation pluriannuelle de l’énergie (PPE) comporte une clause qui spécifie que le recyclage des principaux composants des éoliennes sera rendu obligatoire d’ici 2023. Cette perspective est à l’origine de la création d’une filière française pour le démantèlement des éoliennes en fin de vie. Dénommée D3R elle vise la Déconstruction des parcs éoliens, le Reconditionnement des gros composants, le Recyclage des pales et la Revente des métaux, des matériaux recyclés et des composants. A terme, plusieurs centaines d’emplois seront créés.

Démontage et remise en état du site

Il existe un marché de l’occasion pour les anciennes éoliennes. Elles prennent parfois le chemin de la Pologne ou de la Russie pour y poursuivre une seconde vie. Mais, le plus souvent elles sont mises au rebut. Les turbines sont alors démontées. Si le site n’est plus utilisé pour l’exploitation du potentiel éolien, il est débarrassé de tous les équipements liés au projet et le terrain restitué à son usage initial ou à une autre destination approuvée.

En France, la règlementation précise, dans un article du Code de l’environnement, que l’exploitant est responsable de la remise en état du site. A cet effet, les promoteurs doivent, au moment de la construction d’un parc, provisionner une somme de 50.000 € par éolienne pour son futur démantèlement. Les premiers démontages effectués en France ont montré que ce montant correspond au coût réel. Un arrêté ministériel impose l’enlèvement des câbles électriques enterrés, l’excavation des fondations sur une profondeur minimale de 1 mètre (dans le cas de terrains agricoles) et leur remplacement par des terres dont les caractéristiques sont comparables au sol en place. Les aires de grutage et les chemins d’accès doivent aussi être déconstruits sauf si le propriétaire du terrain souhaite les conserver. L’avis de celui-ci sur la remise en état du site est une des pièces qu’il faut annexer à la demande d’autorisation. Dans le cadre de la location de son bien à l’exploitant éolien ce propriétaire peut d’ailleurs fixer, dans une convention de droit privé, des conditions de remise en état plus contraignantes que celles prévues par les textes législatifs, par exemple l’enlèvement complet des fondations.

En Belgique la réglementation prévoit des règles similaires. La provision à constituer pour le démantèlement est toutefois plus importante et varie en fonction de la puissance de la turbine.

Recyclage

Les parties métalliques comme le mat et le rotor constituent plus de 90 % du poids des aérogénérateurs et se recyclent sans problème dans les filières existantes. La valeur marchande de ces ferrailles fait d'ailleurs souvent du démontage d'une éolienne une opération rentable. Le béton armé des fondations peut aussi être facilement valorisé : trié, concassé et déferraillé il est réutilisé sous la forme de granulats dans le secteur de la construction. La vidéo ci-dessous illustre une opération de démolition et de recyclage de la fondation d'une éolienne.

Que fait-on des pales ?

Les pales d'une éolienne sont constituées de matériaux composites à base de fibres de verre ou de carbone difficiles à recycler. On estime pourtant que d'ici 2021 plus de 50.000 tonnes de pales d'éoliennes seront déclassées. L'industrie s'est donc mobilisée pour trouver des solutions. Le problème est d'ailleurs plus vaste que celui du recyclage des éoliennes puisque ces mêmes matériaux sont utilisés pour de nombreuses autres applications, comme par exemple les coques de bateaux et de kayaks, les planches à voiles, des réservoirs, des éléments de carrosserie dans la construction automobile, des pièces pour l'aéronautique, etc.

Une première difficulté réside dans l'encombrement de ces pales dont la longueur peut varier entre 20 et 50 mètres. Leur transport en une pièce vers les usines de recyclage serait une opération coûteuse et fastidieuse. C'est la raison qui a incité la multinationale française Veolia à mettre au point une grande scie à pales d'éoliennes qui permet de les découper en morceaux, directement sur place, rendant leur transport plus aisé.

Cabinet d'Expertise en Aéronautique - Inscrit près la cour d'appel d'Amiens – Indépendant de l'EASA
15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

Elles peuvent alors être broyées et valorisées comme combustible dans les cimenteries, en remplacement des carburants fossiles traditionnellement utilisés. Les cendres servent ensuite de matière première dans la fabrication du ciment. Cette technologie évite donc la production de déchets.

Une autre possibilité consiste à utiliser le broyat de pales pour fabriquer de nouveaux matériaux composites. C'est notamment la solution mise au point par l'Université de Washington en collaboration avec General Electrics (GE) et Global Fiberglass Solutions Inc (GFSI) de Seattle. Le produit baptisé Ecopolycrete obtenu à partir du broyage des pales serait aussi résistant que les composites à base de bois. De très nombreux usages peuvent être envisagés comme des dalles de sol, des glissières de sécurité le long des axes routiers, des plaques d'égout, des skateboards, des meubles ou des panneaux pour le bâtiment. En moins d'un an, GFSI a recyclé 564 pales selon cette méthode, et l'entreprise estime qu'elle pourrait transformer en produits utiles plus de 20.000 tonnes de déchets de matériaux composites dans les deux années à venir.

Une seconde vie pour les pales

A Rotterdam, aux Pays-Bas, un bureau d'architectes a imaginé une utilisation plus originale et ludique pour les anciennes pales d'éoliennes. Il a conçu une aire de jeux en utilisant des morceaux de pales d'anciennes turbines pour aménager des tunnels, des tours, des toboggans, des rampes, des glissières et des obstacles qui font le bonheur des enfants. Ces éléments ont été fixés au sol et peints en blanc avec des bandes de couleurs vives.

ROTTERDAM

Cabinet d'Expertise en Aéronautique - Inscrit près la cour d'appel d'Amiens – Indépendant de l'EASA
15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

Sur la Willemsplein, la municipalité a également installé des bancs publics fabriqués avec des morceaux de pales d'éoliennes. Plus au nord, la ville hollandaise d'Almere, a créé des abribus en utilisant ces mêmes déchets de pales, et au Danemark, on en fait des abris vélo. Selon les estimations, si seulement 5% de la production annuelle de mobilier urbain aux Pays-Bas, tels que les aires de jeux, les bancs publics et les abribus étaient fabriqués avec des pales de turbines déclassées, on pourrait recycler utilement les 400 pales démantelées chaque année dans le pays.

ALLEMAGNE

AALBORG DANEMARK

Parc éolien d'Oléron : l'Agence des aires marines protégées avait dit non

Par Laurent Bordereaux, juriste enseignant-chercheur.

À l'aube du débat public censé s'ouvrir sur le très controversé projet éolien marin d'Oléron, localisé au cœur d'une zone protégée de premier plan, la position très critique de l'ancienne Agence des aires marines protégées sur ce dossier épineux mérite d'être rappelée pour mémoire, en cette année (dite) de la biodiversité… Position rejoignant celle du CNPN (Conseil National de la Protection de la Nature).

Dans un contexte sociétal tendu quant aux enjeux du déploiement français de l'éolien offshore (comme en témoignent aujourd'hui la construction du parc éolien en baie de Saint-Brieuc et les déboires belges du parc dunkerquois…), l'ouverture annoncée du débat public relatif au grand projet éolien marin au large de l'île d'Oléron s'avère bien délicate pour le gouvernement.

Ce projet est en effet situé au cœur d'une zone de protection spéciale (ZPS) au titre de la directive "oiseaux", au cœur d'une zone spéciale de conservation (ZSC) au titre de la directive "habitats", et, en outre, en plein parc naturel marin (parc de "l'estuaire de la Gironde et de la mer des Pertuis" créé en 2015).

Au regard de ces protections (sans compter la proximité de plusieurs réserves naturelles nationales), comment a-t-on pu opter pour une telle localisation ?

A ce sujet, il est à tout le moins instructif de déterrer une note technique de l'ex-Agence des aires marines protégées (établissement public national), en date du 8 juillet 2015, adressée à la préfecture de Charente-Maritime qui l'avait sollicitée (et diffusée aux services compétents de l'État : DIRM, DREAL, DDTM).

Biodiversité et éolien offshore incompatibles

Rappelons que les missions fondamentales de cette Agence dans le domaine de la préservation du vivant marin ont été reprises par l'actuel Office français de la biodiversité (également établissement public national). Nous en livrons ici quelques extraits, qui n'auront sans doute pas manqué d'interroger les maîtres d'ouvrage du projet oléronais, à l'heure du renforcement affiché par l'État de la politique française des aires naturelles protégées, consacré par le projet de loi "climat et résilience".

Il s'agit précisément de l'avis de l'Agence des aires marines protégées sur la zone identifiée au large d'Oléron, dans le cadre, à l'époque, du projet de définition de zones propices lié au troisième appel d'offres pour l'éolien en mer.

Ladite note, particulièrement motivée, conclut très clairement, compte-tenu des enjeux de biodiversité en présence, au caractère non approprié du développement de l'éolien offshore dans ce secteur d'un "intérêt écologique exceptionnel", "site unique au niveau français"…

Agence des aires marines protégées – Note technique de juillet 2015 (extraits ci-dessous en italique, pp. 7-8 de la note) :

[Une "zone propice" au cœur de plusieurs aires marines protégées

La zone propice est située à l'intérieur de la ZPS FR5412026 Pertuis charentais-Rochebonne et du SIC-ZSC FR5400469 Pertuis charentais.

La simple énumération des zones réglementaires désignées sur cette zone fait état des forts enjeux écologiques présents tant pour les habitats, les mammifères marins et les poissons amphihalins que pour les oiseaux.

L'intérêt écologique exceptionnel de ce secteur s'est traduit par la récente création du parc naturel marin de l'Estuaire de la Gironde et de la Mer des Pertuis.

Les Aires Marines Protégées peuvent répondre à différentes finalités et leur existence peut être compatible avec un certain nombre d'usages ; elles peuvent même contribuer à promouvoir le développement de certains d'entre eux. Néanmoins, la mise en œuvre de ces usages doit rester compatible avec la finalité commune à toutes les différentes catégories d'aires marines protégées qui est la protection de la biodiversité. Il s'agit notamment de permettre la constitution, plus qu'ailleurs, de zones de repos, de quiétude pour les espèces. Les pressions, les facteurs de stress doivent y être maîtrisés pour participer de manière efficace aux engagements nationaux en faveur de la biodiversité. (…)

Cabinet d'Expertise en Aéronautique - Inscrit près la cour d'appel d'Amiens – Indépendant de l'EASA

15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

Dès lors, bien que toutes les zones de protection spéciale de la façade atlantique aient été identifiées en enjeu fort dans le cadre de l'exercice de planification pour le 3ème appel d'offre éolien en mer, la zone de protection spéciale des Pertuis-Charentais-Rochebonne revêt une importance particulière au regard de la métropole (enjeu national du à la présence du puffin des Baléares et au nombre d'espèces d'oiseaux marins hivernants). Nous confirmons par ce complément d'analyse que l'inscription en tant que telle, d'une zone propice au développement de l'éolien offshore dans la zone "sud Oléron" serait de nature à compromettre les engagements pris par la France au titre de la directive Oiseaux.]

Enjeux écologiques

Dans ces conditions, quelques questions se posent inévitablement. D'abord, au regard des enjeux écologiques majeurs du site, comment le gouvernement peut-il véritablement envisager un grand parc éolien industriel (qui plus est en mode "posé", aux lourds ancrages dans les fonds marins) ?

Dans le dossier de saisine de la Commission nationale du débat public de février 2021, une puissance de 2 GW (après extension) n'est pas exclue, ce qui conduirait alors à implanter l'un des plus grands parcs éoliens dans une aire marine protégée d'importance nationale. Est-ce seulement entendable ?

La transition énergétique serait-elle devenue aujourd'hui l'unique impératif d'intérêt public majeur de la société française ? Il nous semble pourtant qu'une articulation raisonnable entre les politiques publiques de préservation de la biodiversité et de développement des énergies renouvelables n'est pas impossible…

Ensuite, pour en revenir au dossier d'Oléron, cet avis de l'ex-Agence des aires marines protégées risque, pour le moins, de mettre dans l'embarras l'Office français de la biodiversité (OFB).

Si cet établissement public n'est certes pas juridiquement lié par ladite note, comment imaginer qu'il puisse adopter une position contraire en émettant un avis favorable ? Car le projet étant localisé en plein parc naturel marin, il doit légalement être soumis à l'avis conforme (donc devant être suivi) de l'OFB (art. L. 334-5 C. env.), lequel devra faire l'objet d'une motivation convaincante.

Celle-ci sera bien évidemment examinée avec la plus grande attention. Pour parer l'éventualité d'une déconvenue, le gouvernement sera-t-il d'ailleurs tenté de supprimer cette procédure de l'avis conforme, au nom d'une logique de simplification du cadre juridique de l'éolien marin (dont on ne voit pas la fin) ?

Une zone à éviter pour le CNPN

Quoi qu'il en soit, la position de l'ex-Agence des aires marines protégées rejoint aujourd'hui le tout récent avis du Conseil National de la Protection de la Nature, très ferme, qu'il faut méditer : "(…) il convient d'éviter absolument les zones Natura 2000, et notamment les ZPS Oiseaux, qui par définition représentent les zones les plus riches en termes de biodiversité, sélectionnées après une démarche rigoureuse de près de dix ans sur critères scientifiques objectifs imposés par l'Europe, sous peine de fragiliser les dossiers du point de vue juridique." [CNPN, autosaisine sur le développement de l'énergie offshore en France et ses impacts sur la biodiversité, le patrimoine naturel et les paysages, avis du 6 juillet 2021, p. 70]

L'avenir des aires marines protégées françaises se jouerait-il avec cet invraisemblable projet éolien industriel "oléronais" ? S'il devait se concrétiser, on aurait alors bien du mal à cerner quelles pourraient être les ultimes limites de l'artificialisation de la mer côtière.

N.B : L'intégralité de la note de l'AAMP est disponible ici : http://www.eolien-oleron.fr/sdm_downloads/avis-de-lagence-aires-marines-protegees-2

– Sur le projet éolien d'Oléron, voir le site de la CNDP : https://www.debatpublic.fr/parc-eolien-en-mer-au-large-de-la-nouvelle-aquitaine-445

– L'avis du CNPN du 6 juillet 2021 est disponible ici : Juillet 2021 – Avis biodiversité (developpement-durable.gouv.fr)

– Voir aussi : "L'éolien offshore pourrait-il être contrarié par le droit de l'environnement ?" : https://www.village-justice.com/articles/eolien-offshore-pourrait-etre-contrarie-par-droit-environnement,38836.html

The subject in Europe : Geenpeace

Greenpeace Energy – Energy Cooperative with a Mission accurate as of January 2020

Our Business: More than Clean Energy

Greenpeace Energy is an energy cooperative operating throughout Germany that values responsible and sustainable action more than financial profits. We supply more than 173,000 customers, of which about 13,000 are business customers, with clean electricity and proWindgas, an ecologically superior alternative to natural gas. The business is organised as a cooperative with more than 26,200 members whose contributions provide a solid equity capital base and, thus, stability. The fact that the members are not only the cooperative's owners but also its customers serves to prevent conflicts of interest: towards an ecologically oriented business policy, rather than profit maximisation.

Through our subsidiary Planet energy we build our own power plants. Thirteen wind farms and four photovoltaic plants totalling 90 MW are already in operation. Furthermore, we take a very active role in energy policy discussions and help to set the stage for the energy turnaround: We test new concepts, for example concerning electromobility, and we sponsor research projects to foster innovation and to smooth the way into a future of clean energy.

Our History: Greenpeace Campaign Evolves into Energy Supplier

The liberalisation of energy markets towards in the late 1990s opened up the possibility to supply customers with green electricity. The environmental protection organisation Greenpeace e.V. used the opportunity to develop criteria for high quality green electricity and, through the campaign "electricity switch", gathered supporters who demanded clean electricity. A public tender showed, however, that no supplier was able meet all criteria. Greenpeace e.V. in response took matters into their own hands and initiated in autumn

1999 the foundation of the cooperative Greenpeace Energy, an entity that is legally and financially independent of the environmental protection organisation. Greenpeace Energy started supplying customers with clean electricity according to the Greenpeace criteria on January 1st, 2000, and in 2001 founded the subsidiary Planet energy, which constructs green power plants.

Our Vision: Energy Turnaround now!

Our aim is the energy turnaround - energy supply from ecological sources, without coal and nuclear power. We fight for the environment and encourage as many people as possible to join us in shaping a future of clean energy. We combine political demands with solutions for the energy industry on behalf of our customers and cooperative owners.

Our Products: Join Us - Participate - Reshape the Energy Industry!

- Green electricity: The electricity we supply is exclusively sourced from renewable energy power plants. Since January 2015 we guarantee a share of 10% wind energy in our electricity mix. This minimum share will be increased in the coming years.
- proWindgas: As of 2011, consumers can switch to our new gas tariff proWindgas, the first of its kind in Germany. Its key technology is the conversion of green electricity - especially wind power - into hydrogen. Greenpeace Energy is thus pressing ahead with an innovative storage technology for renewable energy. In October 2011 we started supplying initially pure natural gas. In December 2014, we began to add renewable hydrogen. The gas tariff includes a subsidy of 0.4 ct/kWh for the further development of windgas technologies. That's how we invite our customers to help us shape the energy turnaround.
- Green investment: Our customers can contribute to the construction of wind farms and PV plants by purchasing participation rights. Such investment provides Planet energy with the necessary capital to expand its portfolio of power plants. At the same time, the investors profit from the economic success of the plants.
- Cooperative shares: The organisational form of Greenpeace Energy as a cooperative ensures its independence and transparency. All it takes is a share of €55 to join the cooperative andthereby to own one's energy supplier.

Qu'a-t-il bien pu arriver à cette éolienne ?

Qu'a-t-il bien pu arriver à cette éolienne pour que ses pales se retrouvent épluchées telle une vulgaire banane ? Si les spéculations vont bon train, la réponse est toute simple. Située au Texas, la turbine a été endommagée par une tornade. Des dégâts finalement limités au regard de la puissance du phénomène.

Contrairement à certaines rumeurs relayées sur les réseaux sociaux, cette éolienne n'a pas « fondu » sous la canicule. La turbine, implantée à Wadsworth au sud-est du Texas, s'est retrouvée en mauvaise posture au passage d'une tornade le 14 juin dernier. Les images impressionnantes de l'engin endommagé ont été publiées par le service météorologique NWS Houston sur Twitter ainsi que sur Reddit par un technicien éolien.

Difficile de résister à une tornade

Elles montrent une éolienne aux allures de fleur fanée, dont les pales ont été littéralement épluchées par le phénomène. Composées d'un mélange de bois et de résine, elles n'ont évidemment pas résisté aux vents violents et désordonnés qui peuvent souffler jusqu'à 500 km/h au centre d'une tornade.

Des morceaux de pales auraient également heurté un transformateur au sol, générant un incendie. À l'inverse, le mât et la nacelle en acier ainsi que les fondations en béton semblent parfaitement intacts. La turbine devrait ainsi pouvoir être réparée sans difficultés particulières. Les trois autres éoliennes situées à proximité ont manifestement été épargnées, trahissant la morphologie très localisée d'une tornade.

Comment une éolienne réagit en cas de tempête ?

Il faut savoir que les aérogénérateurs sont généralement capables de fonctionner jusqu'à une vitesse de vent de 90 km/h. Ils disposent d'un système de freinage et d'orientation des pales limitant la prise au vent pour stopper leur rotation en cas de tempête. Dans les zones soumises au risque cyclonique, certaines éoliennes bipales peuvent même être couchées au sol le temps de l'alerte. À l'arrêt, les éoliennes peuvent donc résister à de violentes intempéries.

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15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

What about this month:

New Software Capability Gets Planes Rolling Directly to the Runway, Reducing Fuel Burn & Taxi Time

WASHINGTON—The U.S. Transportation Department's FAA and NASA today announced the completion of research and testing on a software capability that calculates gate pushbacks at busy hub airports so that each plane can roll directly to the runway and to take off. The FAA plans to deploy this capability as part of a larger investment in surface management technology to 27 airports.

An animation of how the software works can be viewed at [Rollin' to the Runway - YouTube]

The future of flight must be more sustainable and environmentally friendly," said FAA Administrator Steve Dickson. "This new capability as part of a flight merging system has a double benefit: It reduces aircraft emissions and ensures air travelers experience more on-time departures."

"NASA is developing transformative technologies that will revolutionize the aviation sector as we know it," added NASA Administrator Bill Nelson. "The proof is in the pudding. This air traffic scheduling technology enhances aircraft efficiency and improves dependability for passengers every day. I'm excited that the software NASA developed for air traffic controllers and airlines will be soon rolled out at airports across the country and know the results will continue to be extraordinary."

The innovative capability, which will be part of the FAA's Terminal Flight Data Manager (TFDM) program, was developed by NASA and tested for nearly four years by the FAA's NextGen group, airlines' airport operations, FAA radar facilities in Charlotte and Dallas/Fort Worth and the Atlanta and Washington, D.C., centers handling high-altitude en route flights.

By minimizing taxi delay and ramp congestion, the program reduces fuel burn and CO2 emissions and support the Biden-Harris Administration's goal to build a sustainable aviation system. During program testing at Charlotte Douglas International Airport, the program:

- Reduced taxi times that helped save more than 275,000 gallons of fuel annually, equivalent to the fuel burn of 185 flights between New York and Chicago by a Boeing 737;
- Reduced greenhouse gas emissions by 8 tons of CO2 daily;
- Reduced delays by 916 hours, equivalent to shaving 15 minutes of waiting time on a taxiway for more than 3,600 departing flights.

Charlotte is currently scheduled next in the FAA's rollout of TFDM, which will include the push-back capability, at 27 hub airports across the country. The FAA anticipates a savings of more than 7 million gallons of fuel every year and the elimination of more than 75,000 tons of CO2 emissions annually.

"When you are ready to go, you want to go. Waiting in line on a taxiway is not part of the flight plan," adds FAA Assistant Administrator for NextGen Pamela Whitley. "Through a productive partnership between the FAA, NASA and the airlines, we now have technology that brings better predictability of aircraft movements on and above our busiest airports. This will yield benefits for air travelers and for the environment."

The airports currently expected to be part of the rollout include: Atlanta, Baltimore, Boston, Charlotte, Chicago Midway, Chicago O'Hare, Dallas-Ft. Worth, Denver, Detroit, Fort Lauderdale, Houston Bush, Las Vegas, Miami, Minneapolis, Newark, New York JFK, New York LaGuardia, Orlando, Philadelphia, Phoenix, Salt Lake City, San Diego, San Francisco, Seattle, Washington Dulles, Washington Reagan National.

EHEST Leaflet HE 9 Automation and Flight Path Management

This leaflet identifies current best practice on automation and flight path management. Over the years helicopter manufacturers have used more automation to assist crews and reduce manual flying workload. The rapid advances in technology have given rise to significant capabilities. Automation has contributed substantially to the sustained improvement of flight safety. Automation increases the timeliness and precision of routine procedures reducing the opportunity for errors and the associated risks to the safety of the flight.

The helicopter community has however experienced incidents and accidents where automation and complex flight displays have been significant factors.

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This leaflet reviews the basics of automation and provides a list of principles for optimal use of automation and flight path management.

Travelcare for travelers and crewmembers

ICAO or FAA

PackSafe for Passengers

Some of the items you pack in your baggage may be considered dangerous goods, also known as hazardous material. Most dangerous goods are forbidden in carry-on and checked baggage. There are a few exceptions for some personal items such as toiletries, medicines, and assistive devices. Check the chart below to see which common dangerous goods are allowed in checked and/or carry-on baggage and which are not. Remember, this is just a listing of common dangerous goods; if you don't see your item here it doesn't mean it's allowed in baggage. When in doubt, leave it out!

Security Screening Questions: The Transportation Security Administration also has rules on "prohibited items" that pose a security threat. Though they sometimes overlap, the TSA security rules are separate from the FAA dangerous goods safety rules; go to the TSA Prohibited Items web page.

See link QR Code

European Advice

EASA publishes Flight Data Monitoring of new safety issues arising from the COVID-19 pandemic

The COVID-19 pandemic has posed many new safety issues and changes to safety priorities for operators. These changes may require adapting the scope of the Flight Data Monitoring (FDM) programmes and their way of operating.

This analysis document was presented at a FDM workshop of EASA SAFE360° – 2021 and covers the following topics:

- What has been the impact of the COVID-19 pandemic on the FDM programmes?
- What do the new safety issues brought by the pandemic mean for FDM programmes?
- What is the foreseeable impact of a return to normal operations?

The document was prepared in collaboration with FDM experts from the aviation industry. It contains industry good practice. The document does not have the status of official EASA guidance.

French Advice (in French)

Other purposes

Environment

Français

joe_20210904_0206_0002 - LOI n° 2021-1104 du 22 août 2021 portant lutte contre le dérèglement climatique et renforcement de la résilience face à ses effets (rectificatif)

Éolien en mer : "la croissance va s'installer durablement"

A l'occasion de la 5e édition de Seanergy, forum international dédié aux énergies marines renouvelables (EMR) et à l'éolien offshore, qui se tiendra du 21 au 24 septembre à Nantes et Saint-Nazaire, nous avons voulu faire un point sur l'éolien en mer qui se développe le long des côtes françaises. Interview de Marc Lafosse, président de Bluesign, société organisatrice de Seanergy.

Quelle est l'ambition de cette nouvelle édition ?

Seanergy a pour objectif de promouvoir la filière et de renforcer les synergies entre tous les acteurs pour accélérer sa structuration et favoriser son développement, en France et dans le monde.

En stimulant la collaboration entre politiques, industriels et académiques, Seanergy a pour ambition de contribuer à faire des Energies de la mer, les énergies de demain, au service de la transition énergétique.

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Y a -t-il des nouveautés cette année ?

Un Village Innovation permettra à des jeunes entreprises de proposer leurs solutions innovantes pour la transition énergétique bleue et d'émerger ainsi parmi les acteurs établis du marché. Nous avons en outre associé à cette espace les investisseurs qui y présenteront leurs solutions d'accompagnement et de financement pour ces entreprises.

L'éolien en mer prend son envol en France. Redoutez-vous encore les freins liés aux contestations notamment de certaines filières comme celle des pêcheurs ?

La filière de l'éolien posé connait une très nette croissance du fait du démarrage de la construction des premiers parcs attendus depuis plusieurs années.

Cette nouvelle étape structurante pour cette filière a un impact immédiat sur son nombre d'emplois en France avec une augmentation très significative de 59% selon l'observatoire des énergies de la mer 2020.

Cette croissance va s'installer durablement si l'on en croit la planification des mises en service des parcs attribués.

L'éolien posé joue son rôle d'entrainement pour les filières qui suivent, comme l'éolien flottant, l'hydrolien ou le houlomoteur. Cette courroie de transmission va aussi permettre de montrer et d'acculturer le grand public et les usagers de la mer aux énergies de la mer en France.

C'est une étape importante, notamment, pour répondre aux interrogations sur les usages et la cohabitation des professionnels de la mer. Il n'y a pas de freins à redouter, mais plutôt une attente collective de comprendre, partager, monter en compétences, gagner de l'expérience.

L'éolien offshore est l'avenir des renouvelables en France. Le coût des installations peut-il remettre en cause l'intérêt des investisseurs ?

Il ne faut pas confondre les niveaux d'investissements, qui sont effectivement colossaux, et la compétitivité de la filière, qui est tout à fait exemplaire dans le paysage des renouvelables.

Les investisseurs ont au contraire beaucoup d'appétence pour la filière comme en témoigne l'attractivité des appels d'offres français avec 10 consortiums sélectionnés par l'Etat pour entrer en dialogue compétitif pour la première ferme commerciale d'éoliennes flottantes au monde dans le sud Bretagne, ou encore 6 consortiums pré-sélectionnés en Normandie pour le futur parc éolien posé au large du Raz Barfleur.

Vous sentez-vous soutenus par l'Etat français ?

La réponse courte est oui, oui du côté de l'éolien en mer. L'Etat, depuis la publication de la PPE, tient ses engagements de volumes dans le domaine de l'éolien posé et flottant. C'est une bonne base pour consolider une nouvelle filière qui peut déjà s'enorgueillir de réussir sa montée en compétence.

Je cite souvent l'exemple de la Région Normandie, qui a en quelques années réussi à mariniser sa production d'énergies renouvelables en ajoutant aux 800 MW d'éolien terrestre 3 500 MW d'éolien en mer.

Et ce n'est pas fini, il faut désormais se préparer à une accélération. Plusieurs scenarios ou études l'envisagent sérieusement : les scenario RTE 2050, ceux de l'ADEME ou encore le rapport de la commission prospective de la CRE. Si l'Etat souhaite s'y engager, il faudra également faire grossir les équipes de la DGEC en charge de mener ces appels d'offres.

Du côté des autres énergies marines, hydrolien, houlomoteur et SWAC en Outre-mer, l'Etat est encore un peu timide, et accorde son soutien exclusivement du côté de la R&D encore nécessaire à l'émergence de ces filières via le programme des investissements d'avenir et son opérateur privilégié, l'ADEME.

La filière connait cependant de belles avancées, et on attend désormais de l'Etat qu'il poursuive son appui aux premières fermes pilotes d'hydroliennes en développement sur les côtes bretonnes et normandes et qu'il reconnaisse le potentiel du houlomoteur à l'instar de nombreux autres pays européens.

L'Union européenne est quant à elle déjà convaincue, et a fixé des objectifs ambitieux de 100 MW installés en 2025, 1 GW à 2030 et 50 GW à 2050.

La crise sanitaire, qui pourrait durer, a-t-elle un impact sur la construction des futurs parcs éoliens ?

La période que nous venons de vivre a montré une certaine forme de résilience, malgré tout il faut espérer que nous ne revivions pas cette mise en pause mondiale de début 2020.

Il faut rester vigilant sur la disponibilité et le nombre de navires qui permettent la construction des parcs qui ne sont pas assez nombreux en Europe. La moindre perturbation engendrée par la crise sanitaire ou autre a des conséquences de planning très impactantes.

Je ne peux aussi que pointer du doigt le risque de ne pas tenir d'évènements comme SEANERGY ! Les industriels ont besoin de se rencontrer et de faire du business. Ce salon en est la preuve ! Alors pour reprendre des couleurs, rendez-vous à Nantes & St Nazaire du 21 au 24 septembre …

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15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

La première pale d'éolienne recyclable est désormais commercialisée

Siemens-Gamesa annonce lancer sur le marché la première pale d'éolienne recyclable au monde. Destinée aux turbines offshore, la pièce est composée d'une résine pouvant être récupérée et réutilisée en fin de vie.

La pale était le dernier gros élément non-recyclable d'une éolienne. Désormais, les opérateurs de parcs offshores peuvent opter pour un modèle valorisable au terme de sa carrière. Siemens-Gamesa vient en effet d'annoncer la commercialisation de sa «RecyclableBlade», une pale composée comme son nom l'indique de résine recyclable. Ce produit indispensable pour lier les fibres et les autres composants en rendant la structure à la fois solide et légère, ne pouvait jusque-là pas être transformé en vue d'être réemployé. Un certain nombre de pales terminaient donc leur vie broyées puis stockées en décharges.

L'Allemagne, premier pays à en bénéficier

Six premiers exemplaires de la « Recyclableblade » ont déjà été produits dans l'usine Siemens-Gamesa d'Aalborg au Danemark. Le fabricant annonce d'ailleurs avoir conclu des accords avec trois clients majeurs tels que les énergéticiens allemands RWE et WPD ainsi que le français EDF Renouvelables. Les pales seront inaugurées sur le parc éolien en mer de Kaskasi en Allemagne, actuellement en construction. Ce dernier comptera 38 turbines du fabricant développant une puissance nominale de 8 MW.

Siemens-Gamesa reste toutefois avare en détails concernant la composition de sa nouvelle pale. Il évoque seulement « une combinaison de matériaux moulés avec de la résine » dont « la structure chimique […] permet de séparer efficacement la résine des autres composants en fin de vie ». Dans son communiqué de

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presse, le fabricant fait également l'impasse sur le taux de valorisation de l'élément. Il se contente d'assurer que « les matériaux peuvent être réutilisés pour de nouvelles applications après séparation ».

Hydrogène : promesse d'un futur décarboné ?

Eclairage signé Nadine Dabouz et Anthony Frescal – Directeur du pôle Énergie et Commerce chez mc2i

La production d'énergies renouvelables, par définition intermittente et non pilotable, est contraignante. Elle met en avant la problématique du stockage de l'électricité qui ne peut être adressée efficacement aujourd'hui par les technologies dont nous disposons.

C'est dans ce contexte que l'utilisation de l'hydrogène comme vecteur d'énergie est une solution envisagée en réponse à l'augmentation croissante de la part du renouvelable dans le mix énergétique français.

Depuis la crise due à la pandémie de COVID-19, la France a mis en place une stratégie d'investissement de plus de 7 milliards d'euros avec un objectif annoncé : devenir un acteur incontournable à l'échelle mondiale du secteur via un plan de relance économique qui devrait générer entre 100 à 150.000 emplois directs et indirects d'ici à 2030.

L'hydrogène est une particule pleine de ressources …

Découvert au milieu du XVIIIe siècle, l'hydrogène est l'élément chimique le plus simple, son isotope le plus commun est constitué d'un proton et d'un électron : cela en fait l'atome le plus léger de notre univers. Le dihydrogène, par son vrai nom, possède un fort potentiel de stockage qui est en revanche difficilement exploitable dans les conditions normales de température et de pression.

… dont la synthèse, grâce à plusieurs techniques, en fait un vecteur pour le stockage de l'électricité…

L'hydrogène présente un intérêt comme « vecteur », c'est-à-dire comme passerelle entre sources primaires d'énergie et des usages finaux.

Plusieurs techniques existent pour produire de l'hydrogène :

Le reformage du gaz naturel à la vapeur d'eau qui casse les molécules d'hydrocarbure sous l'action de la chaleur pour en libérer le dihydrogène;

L'électrolyse de l'eau qui décompose l'eau en dioxygène et dihydrogène gazeux grâce à un courant électrique;

La gazéification qui permet de décomposer du charbon ou de la biomasse pour obtenir un gaz de synthèse, le "syngas", composé de CO et H2.

…et qui a un rôle important à jouer dans la transition énergétique

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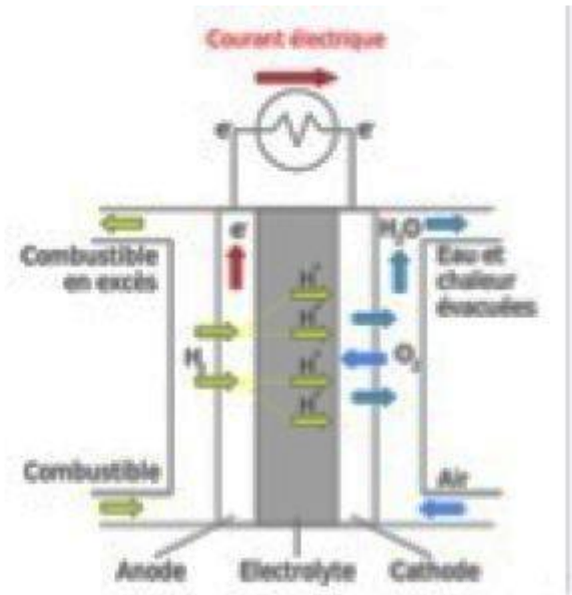
Afin d'atteindre ses objectifs fixés de réduction d'émission de CO2, la France mise donc une partie de sa stratégie sur l'hydrogène bas carbone. À l'heure actuelle, l'hydrogène est issue à 95 % de la transformation d'énergies fossiles – car moins coûteuse – , il est donc indispensable de le fabriquer à partir d'énergies bas carbone.

Nous nous intéresserons essentiellement à l'hydrogène vert, fabriqué par électrolyse de l'eau à partir d'électricité provenant uniquement d'énergies renouvelables.

Le solaire et l'éolien produisent de l'électricité par intermittence et sont non pilotables, il est indispensable de pouvoir stocker le surplus d'électricité généré pour pouvoir l'utiliser lorsque l'ensoleillement et le vent sont insuffisants.

Par ailleurs, l'intégration de plus en plus importante de ces énergies renouvelables sur les réseaux électriques pourrait augmenter la fréquence des jours où la production sera supérieure à la consommation selon les usages de consommation et notamment des véhicules électriques. C'est pourquoi le stockage de surplus d'électricité issu des énergies renouvelables via l'hydrogène semble être une alternative pertinente pour l'avenir. Cela s'appelle le Power-to-Power via la pile à combustible.



En plus du stockage de l'énergie, l'hydrogène a un avenir prometteur dans les bâtiments via les réseaux de gaz avec un marché important à saisir à court terme malgré les défis techniques et logistiques que cela implique.

Il a également un rôle important à jouer dans le secteur des transports via les véhicules lourds, où la question du poids des réservoirs se pose moins que pour l'aviation ou les véhicules légers.

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C'est sur cette base que le gouvernement français souhaite axer sa stratégie nationale pour l'hydrogène sur 3 grands piliers :

Installer 6,5 GW d'électrolyseurs (1/10e de la capacité totale des centrales nucléaires en France) pour décarboner l'industrie et l'économie ;

Développer la mobilité propre des véhicules lourds ;

Créer des emplois dans la filière hydrogène et assurer la pérennité de notre maîtrise technologique.

Malheureusement, l'hydrogène n'est pas exempt du greenwashing

Airbus, fleuron de l'aviation française et européenne a promis, suite au plan de relance économique d'après COVID-19, d'investir massivement dans la R&D pour concevoir un avion commercial tournant à l'hydrogène d'ici à 2035.

À titre d'exemple, la quantité nécessaire pour qu'un avion A320 puisse voler grâce à l'hydrogène nécessiterait une réduction de 40% du nombre de passagers. De plus, 16 centrales nucléaires seraient nécessaires à la production d'hydrogène bas carbone pour conserver le trafic aérien actuel de l'aéroport de Roissy Charles de Gaulle.

Nous sommes donc dans un scénario très hypothétique avec de vrais défis technologiques face à nous.

Dans un tout autre registre, il y a quelques semaines, la tour Eiffel a été éclairée avec de l'hydrogène produit avec de l'électricité. Or le processus de transformation "électricité vers hydrogène vers électricité" aura fait perdre 75% de son rendement initial.

D'un point de vue énergétique, cette initiative consiste à multiplier les émissions de CO2 par 10 pour alimenter la Tour Eiffel. On peut se demander si cette action ne relève pas plus de la communication que d'un souhait de réduire nos émissions de GES (gaz à effet de serre).

Ces deux sujets nous démontrent que le progrès technologique n'est pas une fin en soi et qu'il est important de le mettre en perspective avec les défis qui nous attendent afin d'éviter une dérive vers le superflu.

Actuellement, l'hydrogène est généré à partir d'énergies fossiles qui émettent une grande quantité de CO2 dans l'atmosphère. Pourtant, grâce à son fort potentiel énergétique, cette molécule est un véritable atout pour la transition énergétique si elle est produite à partir d'énergies bas carbone.

De plus, elle permettra de mieux exploiter le potentiel des énergies renouvelables voire d'augmenter leurs parts dans le mix énergétique français. Cependant, il sera nécessaire d'être attentif et démêler le vrai du faux quant à ses potentielles applications pour un futur décarboné.

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Enfin, il faudra prendre en considération le coût des nouvelles infrastructures qui pourrait être répercuté sur le prix de l'électricité.

L'hydrogène deviendra donc attractif par la mise en place de subventions de l'État ou bien via des contrats de compléments de rémunération similaires à la production d'éolien ou de solaire.

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Le couplage parc éolien & stockage par batteries : décollage d'un nouveau modèle énergétique pour les zones isolées ?

Eclairage signé Morgane Réquillart, consultante énergie chez Wavestone (via le blog EnergyStream)

La nécessité de stocker l'électricité produite par les énergies renouvelables, et notamment l'éolien, pour répondre à la variabilité de leur production est incontestablement une thématique d'actualité. Des efforts de recherche ont été engagés tous azimuts pour identifier les technologies de stockage, optimiser l'équation économique et de nombreux organismes ont décidé de soutenir les projets incluant du stockage.

Depuis 2017, la Commission de Régulation de l'Energie a ainsi adopté la « méthodologie stockage » qui permet d'octroyer une compensation financière à des projets de stockage d'électricité dans les zones non interconnectées (zones insulaires non interconnectées au réseau électrique métropolitain français).

Les droits à compensation sont octroyés aux projets dont le gain de coût de fonctionnement (surcoûts de production, coûts du réseau, nécessité d'investissement) est supérieur au coût du stockage ; c'est la notion d'efficience.

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15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

Pourquoi la CRE a-t-elle décidé de soutenir les projets de stockage d'électricité dans les zones non interconnectées ? S'ils permettent d'éviter certains coûts, comment ces projets atteignent-ils l'efficience telle que définie par la CRE ?

Le premier projet français (métropole comprise) de couplage d'un parc éolien avec du stockage stationnaire par batteries est un exemple parlant de projet innovant particulièrement adapté aux spécificités de la zone isolée et constitue un engagement concret pour la transition énergétique. Six ans après son lancement, retour sur le projet de couplage éolien x stockage stationnaire de Marie-Galante.

Un projet innovant pour booster l'autonomie énergétique insulaire

L'île de Marie-Galante, située à 30km de la Guadeloupe, a inauguré en septembre 2015 la première centrale éolienne avec stockage en milieu insulaire en France. Dénommé « centrale de Petite-Place », le parc a été construit à proximité de Capesterre-de-Marie-Galante, deuxième plus grande commune de l'île.

L'île de Marie-Galante compte 11 000 habitants et dépend administrativement et énergétiquement de la Guadeloupe. Près des trois quarts de sa consommation est produite en Guadeloupe, via des ressources à plus de 80% fossiles, et acheminée par un câble sous-marin. La centrale de Petite-Place s'inscrit dans une dynamique ambitieuse de transition vers un approvisionnement énergétique plus diversifié et positionne Marie-Galante comme véritable tête de pont de la transition énergétique des « Zones Non Interconnectées ».

Lors de la COP22 de Marrakech en novembre 2016, l'île était d'ailleurs élevée au rang de modèle de développement durable pour ces zones avec l'ambition de faire de Marie-Galante un territoire à énergie positive.

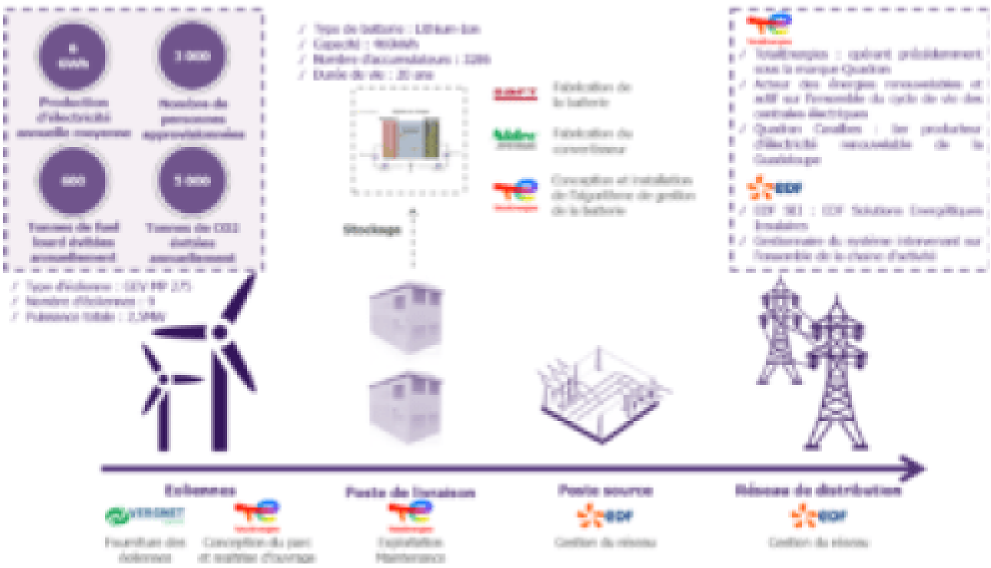
C'est à partir de 2015 que le sujet de l'intégration du stockage aux exploitations ENR prend de l'ampleur grâce notamment à l'intervention du Conseil économique, social et environnemental.

Le CESE a en effet identifié les différentes technologies de stockage existantes et établi des préconisations pour la création d'une dynamique nécessaire à la diminution des émissions de CO2 dans l'optique de la COP21.

Marie-Galante a été la première île française à bénéficier de cette nouvelle dynamique en faveur du stockage de l'électricité, même si la plupart des mécanismes de soutien ont été développés plus tard. La CRE appliquait la « méthodologie stockage » pour la première fois en 2018 ; celle-ci concernait la Corse, la Guadeloupe, la Guyane, la Martinique et la Réunion et retenait 11 dispositifs de stockage centralisés pour une puissance totale de 50 MW, ce qui économiserait 371 M€ de charges sur les vingt-cinq prochaines années.

La centrale de Petite-Place est une exploitation pionnière en France : elle associe des éoliennes, construites spécialement pour répondre aux conditions de l'île, et des batteries.

Mode de fonctionnement et acteurs de la centrale de Petite-Place :



L'aspect des éoliennes du parc de Petite-Place est différent de celui plus connu des parcs éoliens de la métropole. Comme l'illustre le tableau ci-après, les éoliennes du parc ont une envergure plus restreinte que ce que l'on observe habituellement. Marie-Galante est sujette à des contraintes particulières, notamment le passage de cyclones de mai à novembre. La structure spécifique des éoliennes de son parc permet une meilleure résistance à ces événements météorologiques tout en assurant la couverture des besoins en

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électricité de la totalité des habitants de Capesterre-de-Marie-Galante. Le mât des éoliennes, haubané et basculant, est également équipé d'une flèche de manœuvre et d'un treuil, une nouvelle fois pour plus de résistance aux conditions extrêmes de l'île.

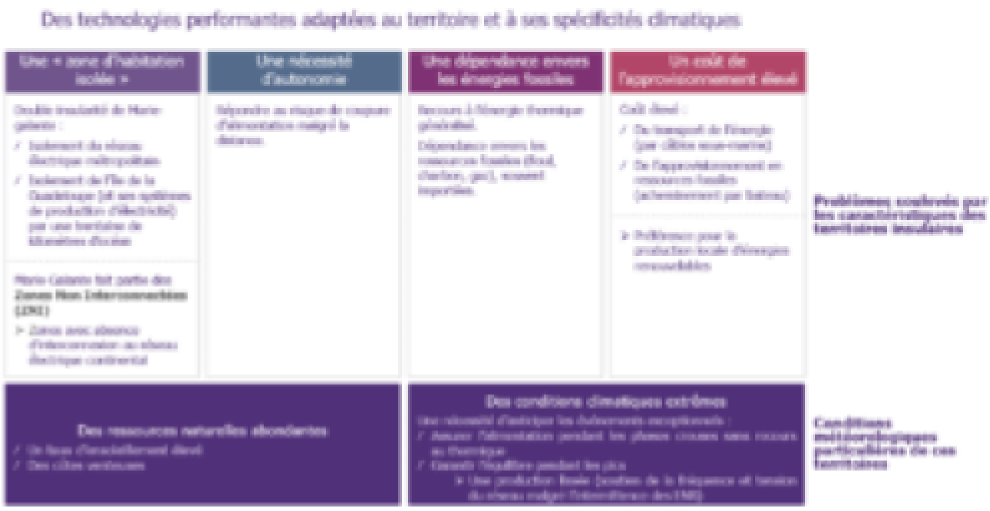
	Eoliennes terrestres « classiques »	Eoliennes de Petite-Place
Puissance unitaire (kW)	2 000	275
Hauteur du mât (mètres)	100	50
Diamètre du rotor (mètres)	Jusqu'à 125	32

La batterie Lithium-ion qui assure le stockage de l'énergie, et soutient ainsi la tension et la fréquence du réseau, est composée d'environ 3 200 accumulateurs regroupés dans un conteneur, pour une durée de vie de vingt ans. Ce conteneur conçu par Saft pour garantir un fonctionnement performant, est capable de résister à des conditions climatiques difficiles. Néanmoins, la capacité cumulée de stockage de la batterie est limitée à l'équivalent de moins d'une heure de production de 2 des 9 éoliennes à leur puissance nominale.

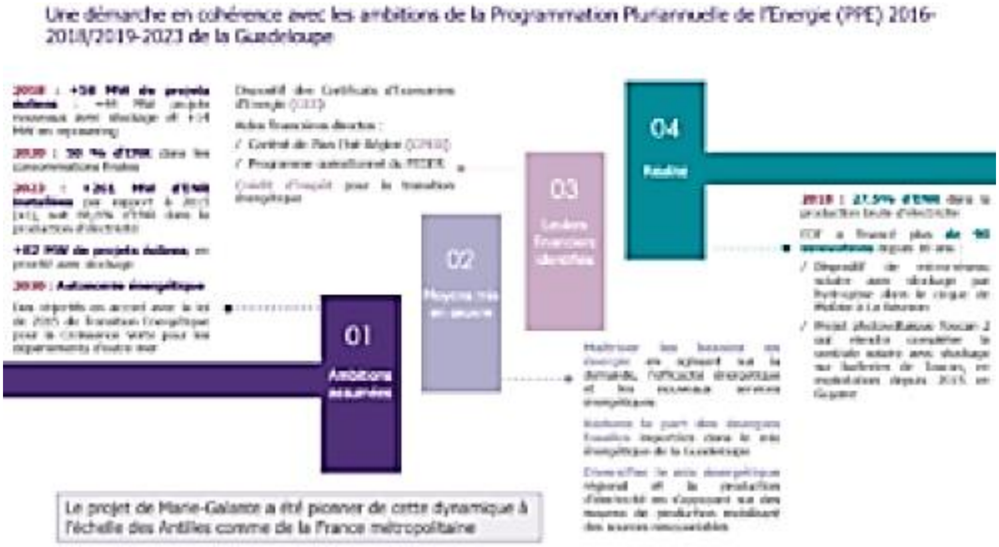
Le parc offre une facilité d'exploitation grâce à un algorithme de gestion permettant chaque jour d'établir la production électrique du lendemain en croisant les prévisions météorologiques avec les capacités et disponibilités des éoliennes. Ces prévisions de production sont ensuite envoyées au gestionnaire du réseau EDF SEI, lui permettant de mieux gérer le système électrique et de réguler la production quotidiennement.

Des technologies performantes adaptées au territoire et à ses spécificités climatiques

La centrale de Petite-Place permet la réponse aux enjeux particuliers des territoires insulaires comme décrit ci-après.



Chacun des territoires d'Outre-Mer fait l'objet d'une Programmation Pluriannuelle de l'Energie (PPE) qui lui est propre. En effet, les objectifs de transition énergétique diffèrent de ceux définis pour la métropole et sont pour la grande majorité plus ambitieux en termes d'intégration des ENR à la matrice énergétique des territoires. Par son rattachement administratif à la Guadeloupe, Marie-Galante suit les objectifs définis dans la PPE de la Guadeloupe.



Quel avenir pour le couplage de l'éolien et du stockage ?

La centrale de Petite-Place à Marie-Galante est un exemple concret de couplage entre énergie éolienne et stockage par batteries en zone insulaire, réalisé grâce à l'intervention de divers acteurs aux expertises complémentaires. Elle répond à des enjeux spécifiques au milieu, tels que la nécessité d'autonomie pour faire face aux imprévus météorologiques et à l'isolement.

C'est la première expérimentation de ce type en France, et elle a depuis été reproduite par de nombreuses entreprises françaises spécialisées dans la conception et l'exploitation de parcs renouvelables.

Néanmoins ces projets en France métropolitaine restent limités et se concentrent plutôt en outre-mer : Nouvelle-Calédonie, La Réunion, Guyane, etc. Nous pouvons nous demander si le modèle va se généraliser puisque, si dans le cas d'un milieu insulaire, le couplage éolien x stockage stationnaire se justifie, il est pertinent de se poser la question pour d'autres environnements.

En effet, les coûts de ces installations restent la plupart du temps prohibitifs et l'impact environnemental n'est pas toujours positif en raison de l'extraction des métaux des batteries ainsi que la difficulté de leur recyclage.

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English

Build back better. Blah blah blah

'Build back better. Blah blah blah': Greta Thunberg mocks Boris Johnson and other 'so-called world leaders' over 'empty promises' as she opens youth climate summit in Milan

- Greta Thunberg mocked Boris Johnson at opening of climate summit in Milan
- The 18-year-old activist quoted one of the Prime Minister's speeches on climate back in April, before adding: 'Blah, blah, blah' to a round of applause
- Thunberg went on to accuse politicians of offering 'empty promises' on climate
- Milan summit comes in advance of the COP26 which the UK will host in Glasgow

Greta Thunberg mocked Boris Johnson as she opened a climate summit in Italy today - accusing them of making 'empty promises' over global warming.

Quoting a speech that Mr Johnson gave back in April, she said: 'This is not about some expensive politically correct dream of bunny hugging, or build back better, blah blah blah. Green economy, blah blah blah, net zero by 2050, blah blah blah.'

Thunberg, who rose to fame thanks to her 'school strike for climate' protests in her native Sweden, then added: 'This is all we hear from our so-called leaders.

'Words that sound great but so far have not led to action. Our hopes and ambitions drown in their empty promises.'

She also attacked governments for 'shamelessly congratulating themselves' while making insufficient pledges to cut greenhouse gas emissions.

Mr Johnson made the 'bunny hugger' remark during a virtual climate summit in April this year, when he also used the phrase 'build back better'.

'What I'm driving at is this is about growth and jobs...' he told world leaders. 'We can build back better from this pandemic by building back greener.'

It is not the first time that Greta has picked up on the remark, changing her Twitter status to 'bunny hugger' just a day later in response.

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Her latest remarks were made at the Youth4Climate summit in Milan - a three-day event attended by 400 young representatives from 190 nations which will be used to develop climate policies.

It runs until September 30, which is the first days of the Pre-COP conference - a summit of energy and climate ministers from around the world in preparation for the full COP26 meeting in Glasgow later this year.

On the final day of the youth summit, the young representatives will present their policies to ministers - with the best taken to Glasgow for discussion by world leaders.

Greta arrived at the summit after a seven-hour train journey from Frankfurt - where she has been pressuring Germany's election candidates over climate change.

She was swarmed by reporters at the station, while she waited to take a mandatory Covid test.

When asked what she was expecting from the talks, Greta gave a typically-downbeat assessment - replying 'not a lot' before adding that it will be 'just like any other meeting, with lots of talking.'

Thunberg was addressing the Youth4Climate portion of the Pre-COP conference, which is the last formal meeting between climate energy ministers from around 50 nations ahead of the main COP26 summit in November.

The aim of Pre-COP is to lay the groundwork for high-level deals to be struck at COP26 itself, when it is hoped major economies will commit to drastic cuts in carbon emissions with the aim of reaching 'net-neutral' by 2050.

Pre-COP runs from September 30 to October 2, with the Youth4Climate summit taking place just before - from September 28 to 30.

During the youth event, some 400 young delegates from 190 countries will hold round-table discussions and workshops to develop climate policies that will be presented to ministers on the final day of the meeting.

The best will be taken to the COP26 summit itself, to be discussed by world leaders and their teams.

Events were originally scheduled to take place in 2020, but have been delayed by a year due to the Covid pandemic.

Also addressing the event was Alok Sharma, the UK minister serving as president of COP26, who said the time has come for bolder commitments from world leaders to cut greenhouse gas emissions.

Sharma said the response of world leaders to the climate change crisis to-date has not come anywhere close to the scale of the challenge.

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The U.N. COP26 conference in Glasgow in November aims to secure more ambitious climate action from the nearly 200 countries who signed the 2015 Paris Agreement.

At that summit, world leaders had agreed to try to limit human-caused global warming to 1.5C - a target the UN has since warned is likely to be missed.

In a report published in August this year, UN experts said humans are 'unequivocally' to blame for climate change and that irreversible damage has already been caused.

It also laid out a grim vision of what will happen in the years ahead even if drastic action to cut emissions is taken immediately, calling it a 'code red for humanity',

But, the report was keen to point out, there is no 'cliff-edge' for climate change - a point at which the situation becomes hopeless and action is not worth taking.

Every degree the planet warms will make life harder - including more frequent droughts, forest fires, flooding, hurricanes and extremes of temperature - while every action to limit the damage will make things easier.

British Prime Minister Boris Johnson has vowed to make the UK a world leader in reducing emissions with ambitious plans to replace gas boilers with hydrogen and a ban on the construction of fossil-fuelled cars including hybrids from 2033.

However, he has been facing pressure to explain exactly who will end up footing the bill - with some estimating the measures could end up costing the average household £28,000.

FAA Invests $431.8M to Increase Safety, Reduce Environmental Impact at Airports

Grants awarded to 60 airports across U.S.

WASHINGTON – The U.S. Department of Transportation's Federal Aviation Administration (FAA) awarded more than $431.8 million in grants to build safer, more sustainable and more accessible airports across the United States. The funding from the final round of Fiscal Year 2021 Airport Improvement Program grants will pay for projects at 60 airports in 31 states plus Puerto Rico and the U.S. Virgin Islands. View an interactive map with all the awards.

"To get passengers where they need to be safely and sustainably, we must make ongoing investments in our aviation system. These grants will help fulfill our commitment to build a safer, more equitable and more sustainable future," said Transportation Secretary Pete Buttigieg.

Thanks to President Biden's American Rescue Plan, the projects announced today will not have to pay the usual local match given the nearly $100 million provided in the law.

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"With today's awards, the FAA has provided $3.2 billion in airports funds this year to improve safety, environmental stewardship, and accessibility," FAA Administrator Steve Dickson said. "These grants support airport infrastructure across our National Airspace System, providing federal investment to communities of all sizes, from remote areas to major metropolitan cities."

Today's grants include:

Increase Safety, Expand Capacity and Create Jobs:

- Bozeman Yellowstone International Airport, Bozeman, Mont.: $5.0 million to construct a 28,800 square-yard general aviation parking area.
- Dallas-Fort Worth International Airport, Fort Worth, Texas: Two grants totaling $35.0 million. The first, for $30.7 million, pays for constructing two replacement aircraft rescue and firefighting buildings to help the airport meet FAA safety requirements. The second, for $4.3 million, will be used to buy zero-emissions passenger shuttle buses and associated charging infrastructure.
- Detroit Metropolitan Wayne County Airport, Romulus, Mich.: $35.6 million to enhance overall airfield safety by reconstructing a taxiway. This is the first phase of a project to reconstruct 6,700 feet of existing taxiway pavement to eliminate potential debris from deteriorating pavement and remove a direct connection between an apron and a runway.
- Gallatin Airport, Sparta, Ky.: $7.9 million to fund the third of four phases of a new airport in Gallatin County, Ky. This phase paves and marks 5,000 feet of the primary runway, 1,800 feet of taxiways, and 75,000 square yards of the terminal apron and constructs 3,200 feet of terminal access road. This new airport will serve a growing industrial and tourism economy and provide accessibility to the Kentucky Aviation System.
- Grand Junction Regional Airport, Grand Junction, Colo.: $15.7 million to construct a new 10,500-foot replacement runway to meet FAA standards, including grading and drainage features.
- Venice Municipal Airport, Venice, Fla.: $2.1 million to extend a taxiway to 5,000 feet. This project will reduce the time planes remain on the runway and enhance safety by eliminating the need for arriving aircraft to back-taxi on a runway.

Build More Sustainable Airports:

- Albuquerque International Sunport, Albuquerque, N.M.: $7.1 million to buy zero-emissions passenger shuttle buses and associated charging equipment, low-emission airport pre-conditioned air units, low-emission airport ground power units and to reconstruct a taxiway.
- Bismarck Municipal Airport, Bismarck, N.D.: $5.6 million to install airfield drainage and storm sewer improvements. This grant funds the seventh phase of a project to move approximately 60 acres of wetlands from the airport property to 11 miles east of the airport, which reduces the risk of wildlife/aircraft strikes at the airport while maintaining valuable wetland areas.
- Denver International Airport, Denver, Colo.: $8.7 million to support Voluntary Airport Low Emissions (VALE) projects for airport air quality improvements.

- Memphis International Airport, Memphis, Tenn.: $24.8 million to build a deicing pad with associated facilities as part of the overall airport modernization project. The deicing facility will address environmental concerns by preventing water runoff from deicing pads.
- Sacramento International Airport, Sacramento, Calif.: $4.6 million to buy zero-emissions passenger shuttle buses and associated charging equipment.
- Tampa International Airport, Tampa, Fla.: $3.8 million to buy zero-emissions passenger shuttle buses and associated charging equipment.
- Increase Access for Rural, Remote Communities:
- Metlakatla Airport, Metlakatla, Alaska: $6.5 million to repair the seaplane base so it can be used to safely transport goods and services to remote communities in Alaska, including the Metlakatla Indian Community on Annette Island in southern Alaska.

The Airport Improvement Program receives approximately $3.2 billion in funding each year. The FAA awarded more than 1,700 grants in 2021. A complete listing of grants and AIP Grants Data by State is on the FAA website.

FAA Continuous Lower Energy, Emissions, and Noise (CLEEN) Program

The Continuous Lower Energy, Emissions and Noise (CLEEN) Program is the FAA's principal environmental effort to accelerate the development of new aircraft and engine technologies. Through the CLEEN Program, the FAA is a cost-sharing partner with industry. CLEEN projects develop technologies that will reduce noise, emissions, and fuel burn and enable the aviation industry to expedite integration of these technologies into current and future aircraft. CLEEN is a key element of the NextGen strategy to achieve environmental protection that allows for sustained aviation growth.

About CLEEN

In 2010 the FAA initiated the first CLEEN Program, entering into five-year agreements with Boeing, General Electric (GE), Honeywell, Pratt & Whitney (P&W), and Rolls-Royce. These companies matched or exceeded the FAA funding in this cost-sharing program. Over the five-year period, the FAA invested a total of $125 million. With the funding match from the five companies, the total investment value exceeded $250 million.

Building upon the success of the initial CLEEN Program, in 2015 the FAA initiated a follow-on program, CLEEN Phase II, which continues efforts to achieve the CLEEN goals and develop and demonstrate aircraft technology and alternative jet fuels.

Under the CLEEN Phase II program, FAA awarded five-year agreements to Aurora Flight Sciences, Boeing, Collins Aerospace, America's Phenix/Delta TechOps/MDS Coating Technologies, General Electric, Honeywell, Pratt & Whitney, and Rolls-Royce. These companies match or exceed the awards in this cost-sharing program. The total federal investment has been approximately $100 million over five years.

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To receive funding from CLEEN, industry partners need to contribute at least 100% cost share to the program. Through the first two phases of CLEEN, industry has contributed $388 million of cost share to the CLEEN Program, which has far exceeded the FAA contribution of $225 million.

The goals of the CLEEN Program are tied to the environmental standards that aircraft and engines are required to meet as a part of airworthiness certification. As aircraft technology advances, the FAA has made the CLEEN goals increasingly more aggressive. Further, additional goals have been added in later phases of the program. In 2021, the FAA initiated CLEEN Phase III. Like the first two phases of the CLEEN Program, the third phase of CLEEN will target reductions in aircraft noise, emissions and fuel burn. In a change from prior phases, the third phase of the CLEEN Program also includes goals for community noise exposure and aircraft engine particulate matter emissions. Additionally, whereas the first two five year phases of CLEEN focused on subsonic civil transportation, CLEEN Phase III is open to technologies for both subsonic and supersonic aircraft.

Program Goals

The CLEEN Phase I and II Program goals include developing and demonstrating:

Certifiable aircraft technology that reduces aircraft fuel burn, and/or supports the FAA's goal to achieve a net reduction in climate impacts from aviation;

Certifiable engine technology that reduces landing and takeoff cycle (LTO) nitrogen oxide (NOx) emissions below International Civil Aviation Organization (ICAO) Committee for Aviation Environmental Protection (CAEP) standards, and/or reduces absolute NOx production over the aircraft's mission

Certifiable aircraft technology that reduces noise levels, relative to the Stage 4/5 standards and/or reduces the noise contour area in absolute terms;

"Drop-in" sustainable aviation fuels, including quantification of benefits. Drop-in fuels will require no modifications to aircraft or fuel supply infrastructure.

In addition to the above goals, CLEEN Phase III goals include developing and demonstrating certifiable aircraft technology that:

- Reduces community noise exposure;
- Reduces particulate matter emissions relative to the CAEP/11 standard; and
- Reduces noise levels during the LTO cycle for civil supersonic airplanes and/or reduces absolute NOx emissions for civil supersonic airplanes over the aircraft's mission.

CLEEN Phase III is also focused on assessment of jet fuels that could provide reductions in emissions or improvements in efficiency, including fuels that enable advancements in aircraft and engine design. This includes both conventional and alternative jet fuels.

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uantitative goals for subsonic fuel burn, emissions, and noise reductions under CLEEN Phases I, II, and III

Goal Area	CLEEN Phase I	CLEEN Phas e II	CLEEN Phase III
Noise Reduction Goal	25 dB cumulative noise reduction cumulative to Stage 5		25 dB cumulative noise reduction relative to Stage 5 *and/or reduces community noise exposure*
Fuel Burn Goal	33% reduction (relative to year 2000 best-in-class in-service aircraft)	40% reduction (relative to year 2000 best-in-class in-service aircraft)	20% below CAEP/10 CO_2 standa rd
NO_x Emission s Reduction Goal	60% margin to CAEP/6 landing/tak e-off NO_x emissions standard	70% margin to CAEP/8 landing/take-off NO_x emissions standard	
Particulate Matter Emissions Reduction Goal	–	–	Reduction relative to CAEP/11 standard
Entry into Service Target	2018	2026	2031

For more information on the CLEEN Program, its benefits, and accomplishments to date, please see the [Continuous Lower Energy, Emissions, and Noise (CLEEN) Program | Federal Aviation Administration (faa.gov)]

Fuels Activities

In addition to the aircraft technology development work under CLEEN, phases I and II of the program have supported fuel properties and performance testing and demonstrations. This testing facilitates new sustainable aviation fuel approvals by standard setting organization ASTM International. For more information on the full scope of FAA's SAF activities, please see the Sustainable Aviation Fuels site.

The third phase of the CLEEN Program also aims to advance the development and introduction of hydrocarbon jet fuels for aviation that could enable improvements in fuel efficiency and reductions in emissions. This includes fuel blends. The CLEEN Program is interested in fuels that are drop-in compatible with the existing pipeline and airport fueling infrastructure, but have changes in their composition that could help an aircraft meet the CLEEN Program goals.

Sustainable Alternative Jet Fuels (faa.gov)

Technology Assessment Activities

In addition to the technology and fuel development activities described above, CLEEN conducts independent technology modeling and benefits assessments. This was initially done through the now complete PARTNER Center of Excellence Project 36 with the Georgia Institute of Technology. This work has continued under the Aviation Sustainability Center of Excellence (ASCENT) to model and assess aircraft technology for CLEEN Phase II (ASCENT Project 37), as well as other emerging technologies and their impacts on aircraft environmental metrics (ASCENT Project 10).

Consortium Meetings

The CLEEN program holds biannual consortium meetings occurring in May and November of each year. During the meeting companies provide detailed descriptions of the progress of their technology development projects. While the majority of the meeting consists of government-only review sessions, the meeting also includes one open day where companies share highlights of their work with the general public. Please contact cleen@faa.gov for more information.

The next Consortium Meeting will be held November 1-5, 2021.

If you are interested in attending, please contact us at cleen@faa.gov.

CLEEN Reports & Meetings

Phase 1

- CLEEN Phase I Reports
- CLEEN Consortium Meeting — October 2010
- CLEEN Consortium Meeting — November 2011
- CLEEN Consortium Meeting — November 2012
- CLEEN Consortium Meeting — November 2013
- CLEEN Consortium Meeting — November 2014

Phase II

- CLEEN Phase II Reports
    - *Boeing SEW CLEEN Phase II Final Report (PDF)*
    - *Collins Nacelle CLEEN Phase II Final Report (PDF)*

- *GE FMS Technologies CLEEN Phase II Final Report (PDF)*
- *Pratt and Whitney CLEEN Phase II Final Report (PDF)*

- CLEEN Phase II Consortium Meeting — May 2016
- CLEEN Phase II Consortium Meeting — November 2016
- CLEEN Phase II Consortium Meeting — May 2017
- CLEEN Phase II Consortium Meeting — November 2017
- CLEEN Phase II Consortium Meeting — May 2018
- CLEEN Phase II Consortium Meeting — November 2018
- CLEEN Phase II Consortium Meeting — May 2019
- CLEEN Phase II Consortium Meeting — November 2019
- CLEEN Phase II Consortium Meeting — May 2020
- CLEEN Phase II Consortium Meeting — October 2020
- CLEEN Phase II Consortium Meeting — May 2021

SEE ATTACHED

Sustainable Alternative Jet Fuels

Commercial aviation faces fuel cost, environmental, and energy security challenges that arise from petroleum-based jet fuel use. Sustainable alternative jet fuels can help to address these challenges. Their use could reduce emissions that impact surface air quality and global climate while expanding domestic energy sources that diversify fuel supplies, contribute to price and supply stability, and generate economic development in rural communities.

FAA is working to enable the U.S. use of one billion gallons per year of "drop-in" sustainable alternative jet fuels by 2018. Though these alternative fuels are created from renewable sources, drop-in fuels mimic the chemistry of petroleum jet fuel and can be used in today's aircraft and engines without modification and provide the same level of performance and safety as today's petroleum-derived jet fuel.

Sustainable alternative jet fuel development and deployment is also a key element of the U.S. Aviation Greenhouse Gas Emissions Reduction Plan (PDF).

SEE ATTACHED

FAA provides leadership in this evolving field through activities that support the development and use of sustainable alternative jet fuels. These include:

- Continuous Lower Energy, Emissions, and Noise (CLEEN) Program (see page below) to develop environmentally promising aircraft technologies and sustainable alternative fuels that reduce aircraft noise, emissions, and fuel burn.

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15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

- Airport Cooperative Research Program (ACRP) provides guidance and tools to support deployment of sustainable alternative aviation fuels.
- Alternative Aviation Fuels Broad Agency Announcement (BAA) for research in four priority areas: development of novel "drop-in" alternative jet fuels, alternative jet fuel quality control, sustainability guidance for alternative jet fuel users and performance, and durability testing of new fuels. This announcement closed in 2010.
- Commercial Aviation Alternative Fuels Initiative (CAFFI), a forum for information exchange and coordination among government, academic and aviation industry stakeholders to address challenges and engage with the emerging alternative jet fuels industry.
- Partnership for Air Transportation Noise and Emissions Reduction (PARTNER) Center of Excellence (COE) projects on emissions measurement, sustainability analysis and tool development that improve our understanding of the environmental sustainability, and economic cost of production of alternative jet fuels.

For more information, please see resources and reports organized by topic below.

Information Exchange and Coordination

The Commercial Aviation Alternative Fuels Initiative

Fuel Properties & Performance Testing & Demonstration to support ASTM Approval

- Impact of Alternative Jet Fuel and Fuel Blends on Non-Metallic Materials Used in Commercial Aircraft Fuel Systems CLEEN Project Final Report — Submitted by The Boeing Company (CLEEN program) (PDF)
- (Updated) Impacts of Alternative Jet Fuel and Fuel Blends on Non-Metallic Materials Used in Commercial Aircraft Fuel Systems — Submitted by The Boeing Company (CLEEN program) (PDF)
- Evaluation of Amyris Direct Sugar to Hydrocarbon (DSHC) Fuel — Submitted by Pratt & Whitney (CLEEN progam) (PDF)
- Evaluation of ARA Catalytic Hydrothermolysis (CH) Fuel) — Submitted by Pratt & Whitney (CLEEN program) (PDF)
- Evaluation of KiOR Hydrotreated Depolymerized Cellulosic Jet (HDCJ) Fuel — Submitted by Pratt & Whitney (CLEEN program) (PDF)

Emissions Measurements

- Emissions Characteristics of Alternative Aviation Fuels (PARTNER COE Project 20)
- Environmental and Economic Sustainability Analysis
- Alternative Fuels (PARTNER COE Project 17)
- Ultra Low Sulfur Fuels Cost/Benefits (PARTNER COE Project 27)

- Alternative Jet Fuels Life Cycle Analysis (PARTNER COE Project 28)
- Understanding the Relationship Between Aviation Economics and the Broader Economy (PARTNER COE Project 31)
- Market Cost of Renewable Jet Fuel Adoption in the United States (PDF)
- Alternative Jet Fuel Sustainability (PARTNER COE Project 47)
- The USAF Interagency Aviation Fuel Life Cycle Assessment Working Group "Framework and Guidance for Estimating Greenhouse Gas Footprints of Aviation Fuels" (CAAFI) (PDF)
- Report Evaluating Existing Sustainability Evaluation Programs (Volpe BAA) (PDF)
- Sustainability Criteria and Rating Systems for Use in the Aircraft Alternative Fuel Supply Chain (Volpe BAA) (PDF)
- Greenhouse Gases, Regulated Emissions and Energy Use in Transportation (GREET) Model for Assessing Lifecycle Greenhouse Gases of Alternative Jet Fuel

Alternative Jet Fuel Deployment and Use

- R&D Control Study: Plan for Future Jet Fuel Distribution Quality Control and Description of Fuel Properties Catalog (Volpe BAA) (PDF)
- Biofuel Transportation Analysis Tool: Description, Methodology, and Demonstration Scenarios (PDF)
- Alternative Jet Fuel Readiness Tools (CAAFI)
- Airport Cooperative Research Program (ACRP) Projects on Alternative Jet Fuels

Projections of Future Alternative Jet Fuel Availability

- Volpe Alternative Jet Fuel Scenario Analysis Report (PDF)

SEE ATTACHED

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FAA regulations

The following updates have been made to the Airman Testing webpage:

- Added updated version of the Learning Statements Reference Guide
- Added updated version of the Frequently Asked Questions
- Added updated version of the What's New and Upcoming in Airman Testing document

See attached

Draft ACs

Non changes

Advisory Circular

Number	Title	Publication Date
150/5345-53D	Airport Lighting Equipment Certification Program **(posted 9/16/2021)** **New/Revised Comments:** August 2021 Addendum to AC 150/5345-53D (updated 9/16/2021) Letter Clarifying the Use of Non-Original Equipment Manufacturer (OEM) Components in Certified Airport Lighting Equipment (2/20/2019)	9/26/2012
150/5320-6G	Airport Pavement Design and Evaluation **(posted 6/7/2021)**	6/7/2021
150/5210-17C	Programs for Training of Aircraft Rescue and Firefighting Personnel **(posted 5/28/2021)** **New/Revised Comments:** Addendum for Quarter 3 FY 2021 (5/28/2021)	6/12/2015

Number	Title	Publication Date
150/5230-4B	Aircraft Fuel Storage, Handling, Training, and Dispensing on Airports **(posted 5/28/2021)** **New/Revised Comments:** Quarter 3 FY 2021 Addendum (5/28/2021) Errata Sheet (4/6/2018)	9/28/2012

Forms - Orders & Notices

8020.11D - Aircraft Accident and Incident Notification, Investigation, and Reporting w/ Change 1

1400.9B - Standards and Procedures Essential for Ensuring Access to Airport Facilities by Persons with Disabilities

JO 7400.11F - Airspace Designations and Reporting Points

3900.66A - Flight Standards Service Hearing Conservation Program

8900.596 - Adding Email Fields to OpSpecs/MSpecs/LOAs A001, A006, and A007

JO 1030.2 - Notice of Intent to Revise Federal Aviation Administration (FAA) Order JO 1030.3, Initial Event Response

JO 3000.147 - FAA Order JO 3000.57A, Air Traffic Organization Technical Operations Training and Personnel Certification, COVID Response

8900.595 - Aviation Safety Action Program (ASAP), Voluntary Disclosure Reporting Program (VDRP), and Compliance Program

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EASA regulations

Approval Data Library | EASA (europa.eu)

Rules

Regulations | EASA (europa.eu)

ED Decision 2021/013/R - Regular update of CS-22 — CS-22 Amendment 3

ED Decision 2021/012/R - Regular update of CS-FCD — CS-FCD Issue 2

AMC & GM Part-21 — Issue 2, Amendment 5

Easy access Rules

Agency Decisions

Overview | EASA (europa.eu)

Notices of Proposed Amendment

Notices of Proposed Amendment (NPAs) | EASA (europa.eu)

NPA 2021-10 - Prevention of catastrophic accidents due to rotorcraft hoist issues

NPA 2021-09 - Regular update of the AMC and GM to Regulation (EU) 2019/947 on the rules and procedures for the operation of unmanned aircraft

Opinion

Opinion No 04/2021

A continuing airworthiness management organisation (CAMO) for a single air carrier business grouping

The objective of this Opinion is to address the barriers and inefficiencies that Regulation (EU) No 1321/2014 creates for European Union (EU) air carrier business groupings as regards the management of the continuing airworthiness (CAW) of their fleets.

This Opinion proposes air carriers licensed in accordance with Regulation (EC) No 1008/2008 that form part of a single air carrier business grouping to be allowed to contract a CAMO within that grouping for the CAW management of aircraft operated by them.

The proposed changes are expected to reduce the regulatory burden and increase cost-efficiency for air carrier business groupings mainly by:

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15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

- reducing the duplication of tasks between organisations which have harmonised objectives and procedures; and
- removing barriers to short-time interoperability of aircraft between the air carriers that form part of an air carrier business grouping.

As a consequence, the competitive disadvantage of EU air carriers when compared to other non-EU carriers, will be reduced.

It should be noted that the need to increase efficiency is more significant nowadays due to the impact of the COVID-19 pandemic on aviation.

ASECNA

AIP ASECNA

Regulations

- SUP NR 93/A/21GO - September 25, 2021 - DFFD - OUAGADOUGOU (BURKINA FASO) - Aeronauticals informations update
- SUP NR 92/A/21GO - September 25, 2021 - GOBD - Dakar Blaise DIAGNE (SENEGAL) - Closure runway 01/19 due to works according to the time slot
- SUP NR 91/A/21GO - September 25, 2021 - GA - MALI - Creation of a temporary prohibited area (TPA) and creation inside of two temporary regulated area (TRA)
- SUP NR 13/A/21FM - September 23, 2021 - FMSD - TOLAGNARO / Maurillac (MADAGASCAR) - Update of aeronautical data
- SUP NR 55/A/21FC - September 20, 2021 - FCCC - BRAZZAVILLE NOF - Checklist of valid AIP supplements "A"
- SUP NR 11/B/21FC - September 20, 2021 - FCCC - BRAZZAVILLE NOF - Checklist of valid AIP supplements "B"
- AIC NR 30/A/21GO - September17, 2021 - GGOV - BISSAU (GUINEE BISSAU) - Radar services within BISSAU TMA
- AIC NR 29/A/21FC - September 17, 2021 - FE - CENTRAL AFRICAN - Authorizations of overflight of the central african territory
- SUP NR 54/A/21FC - September 16, 2021 - FCPP - POINTE-NOIRE (CONGO) - Updated of aeronautical information
- SUP NR 90/A/21GO - September 14, 2021 - GA - MALI - Creation of a temporary prohibited area (TPA) and creation inside of two temporary regulated area (TRA)
- VALID NOTAM - GOOO - September 12, 2021 - GOOO - DAKAR NOF - Checklist of valid NOTAM
- SUP NR 89/A/21GO - September 12, 2021 - DXXX - LOME (TOGO) - Parchute jumping exercises
- SUP NR 88/A/21GO - September 12, 2021 - GOBD - Dakar Blaise DIAGNE (SENEGAL) - Closure runway 01/19 due to works according to the time slot
- AMDT 09/2021 - September 09, 2021 - NIL Updating bulletin
- SUP NR 87/A/21GO - September 07, 2021 - DXXX - LOME (TOGO) - Parchute jumping exercises
- SUP NR 86/A/21GO - September 02, 2021 - GOBD - Dakar Blaise DIAGNE (SENEGAL) - Closure runway 01/19 due to works according to the time slot
- SUP NR 85/A/21GO - September 02, 2021 - GOBD - Dakar Blaise DIAGNE (SENEGAL) - Closure runway 01/19 due to works according to the time slot
- SUP NR 84/A/21GO - September 02, 2021 - GABS - BAMAKO (MALI) - Update of contingency flight levels assignment and contingency units members
- SUP NR 10/B/21FC - September 01, 2021 - FKKU - BAFOUSSAM – BAMOUGOUM (CAMEROON) - Update of aeronautical information

- SUP NR 53/A/21FC - September 01, 2021 - FCBB - BRAZZAVILLE/MAYA-MAYA (CONGO) - Obstacle Crane Erection
- VALID NOTAM - FMMM - September 01, 2021 - FMMM - ANTANANARIVO NOF - Checklist of valid NOTAM
- VALID NOTAM - FCCC - September 01, 2021 - FCCC - BRAZZAVILLE NOF - Checklist of valid NOTAM
- SUP NR 12/A/21FM - August 31, 2021 - FMMI - ANTANANARIVO/IVATO (MADAGASCAR) - Update of aeronautical data
- SUP NR 11/A/21FM - August 28, 2021 - FMMI - ANTANANARIVO/IVATO (MADAGASCAR) - Update of aeronautical data
- SUP NR 52/A/21FC - August 19, 2021 - FOOL - LIBREVILLE/LEON M'BA (GABON) - State of operation of some landing aids and deported VHF
- AIC NR 29/A/21GO - August 23, 2021 - GOOO - DAKAR NOF - Check list of aeronautical information circulars - "A" serie
- SUP NR 51/A/21FC - August 19, 2021 - FCCC - BRAZZAVILLE NOF - Checklist of valid AIP supplements "A"
- SUP NR 09/B/21FC - August 19, 2021 - FCCC - BRAZZAVILLE NOF - Checklist of valid AIP supplements "B"
- AIC NR 28/A/21FC - August 12, 2021 - FC - CONGO - Measures that have permitted to curb the spread of Covid-19 pandemic since it appearance
- SUP NR 06/B/21FM - August 19, 2021 - FMMM - ANTANANARIVO NOF - Checklist of valid AIP supplements "B"
- SUP NR 83/A/21GO - August 17, 2021 - GOOO - DAKAR NOF - Checklist of valid AIP supplements "A"
- SUP AIRAC NR 82/A/21GO - August 12, 2021 - GOOO - DAKAR FIR - New allocation and management procedures of SSR codes
- SUP AIRAC NR 81/A/21GO - August 12, 2021 - DRRR - NIAMEY FIR - New allocation and management procedures of SSR codes
- SUP AIRAC NR 80/A/21GO - August 12, 2021 - DGFC - AACCRA FIR - New allocation and management procedures of SSR codes
- SUP AIRAC NR 10/A/21FM - August 12 30, 2021 - FMMM - ANTANANARIVO FIR - New allocation and management procedures of SSR codes
- SUP AIRAC NR 50/A/21FC - August 12, 2021 - FTTT - NDJAMENA FIR - New allocation and management procedures of SSR codes
- SUP AIRAC NR 49/A/21FC - August 12, 2021 - FCCC - BRAZZAVILLE FIR - New allocation and management procedures of SSR codes
- AIC NR 28/A/21GO - August 12, 2021 - DI - IVORY COAST - Travel procedures for passengers from Senegal and Tunisia
- SUP NR 48/A/21FC - August 11, 2021 - FOOG - PORT-GENTIL (GABON) - Operating Condition of some radionavigation and landing aids and Grass Cutting Works
- SUP NR 47/A/21FC - August 10, 2021 - FCBB - BRAZZAVILLE/MAYA-MAYA (CONGO) - Update of Aeronautical informations
- SUP NR 79/A/21GO - August 10, 2021 - DBBB - CARDINAL BERNARDIN GANTIN DE CADJEHOU (BENIN) - Aeronautical informations update

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15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

Notam

Consultation NOTAM (asecna.aero)

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15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

French regulations

JORF

joe_20210924_0223_0025 - Arrêté du 17 septembre 2021 modifiant l'arrêté du 9 juillet 2007 relatif à l'exploitation de services de transport aérien par la société Transavia France

joe_20210924_0223_0024 - Arrêté du 16 septembre 2021 modifiant l'arrêté du 26 décembre 2016 fixant la liste des sites ou services de la direction générale de l'aviation civile en application de l'arrêté du 26 décembre 2016

joe_20210918_0218_0022 - Arrêté du 16 septembre 2021 portant création d'une zone interdite temporaire dans la région de Le Versoud (Isère), identifiée Le Versoud, dans la région d'information de vol de Marseille

joe_20210917_0217_0032 - Arrêté du 7 septembre 2021 modifiant l'arrêté du 3 août 2007 relatif à l'exploitation de services de transport aérien par la société Corsair

joe_20210916_0216_0032 - Arrêté du 8 septembre 2021 modifiant l'arrêté du 24 janvier 1956 relatif aux conditions d'établissement et de perception des redevances d'atterrissage et d'usage des dispositifs d'éclairage sur les aérodromes publics

joe_20210915_0215_0020 - Arrêté du 6 septembre 2021 portant suppression de la voie aérienne Z 57 dans la région d'information de vol de Paris

joe_20210910_0211_0028 - Arrêté du 8 septembre 2021 portant création d'une zone interdite temporaire dans la région de Corbières-en-Provence (Alpes-de-Haute-Provence), identifiée Corbières, dans la région d'information de vol de Marseille

joe_20210910_0211_0027 - Arrêté du 6 septembre 2021 portant création de la voie aérienne X 1 en France métropolitaine

joe_20210905_0207_0031 - Arrêté du 31 août 2021 modifiant l'arrêté du 20 février 2020 relatif à l'exploitation de services de transport aérien de la société COMPAGNIE AERIENNE INTER REGIONALE EXPRESS

joe_20210905_0207_0030 - Arrêté du 31 août 2021 modifiant l'arrêté du 9 juillet 2007 relatif à l'exploitation de services de transport aérien par la société Transavia France

OSAC-DSAC

Bulletin officiel de la DGAC

Bulletin Officiel des Ministères de la Transition écologique et solidaire et de la Cohésion des territoires et des Relations avec les collectivités territoriales (developpement-durable.gouv.fr)

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TRAA2129259A - ARRÊTÉ DU 15 SEPTEMBRE 2021 FIXANT LA LISTE DES CANDIDATS AUTORISÉS, AU TITRE DE L'ANNÉE 2021, À PASSER L'ÉPREUVE DE L'EXAMEN EN VUE DE L'OBTENTION DE LA 2ÈME QUALIFICATION DU CORPS DES TECHNICIENS SUPÉRIEURS DES ETUDES ET DE L'EXPLOITATION DE L'AVIATION CIVILE.

TREA2126779A - ARRÊTÉ DU 23 SEPTEMBRE 2021 FIXANT LE CALENDRIER DES EXAMENS THÉORIQUES DES PERSONNELS NAVIGANTS PROFESSIONNELS POUR L'ANNÉE 2022

European Centre for Cybersecurity in Aviation (ECCSA)

See : https://www.easa.europa.eu/eccsa

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15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

U.A.S. – Drones

See : https://www.easa.europa.eu/eccsa

EASA publishes updated Easy Access Rules for Drones

Easy Access Rules for Unmanned Aircraft Systems | EASA (europa.eu)

The European Union Aviation Safety Agency has published a new revision of the Easy Access Rules for Drones.

This Revision from September 2021 updates the Easy Access Rules for Drones based on Commission Implementing Regulation (EU) 2021/1166 amending Commission Implementing Regulation (EU) 2019/947 as regards postponing the date of application for European standard scenarios.

It is also available as dynamic online publication with filters for obtaining the regulatory material tailored to one's needs, search functions for quickly accessing the relevant sections, and easy navigation for computers, tablets, and mobiles.

The document is generated through the eRules platform and will be updated regularly to incorporate further changes and evolutions to its content.

Night Authorization Available for Part 107 Drone Pilots

Drone pilots with current Part 107 Remote Pilot Certificates may now obtain near real-time authorizations to fly at night through FAA-approved providers of Low Altitude Authorization and Notification Capability (LAANC) services. LAANC is an automated system for drone pilots requesting to fly below 400 feet in controlled airspace often found around airports. Drone pilots need FAA approval prior to flying in controlled airspace.

In addition to the near real-time night authorizations, drone pilots will have more areas they can fly in since the FAA has divided the airspace into smaller segments. Since April 2021, while LAANC providers updated their software, Part 107 pilots were able to operate in controlled airspace at night with a valid LAANC daytime authorization and an authorization letter from the FAA which expires on September 30. Today's announcement provides a permanent solution for Part 107 drone pilots to operate in controlled airspace at night.

For more information on night authorizations and additional LAANC announcements, visit the FAA website. For general inquiries on these new regulations and other UAS inquiries, please call 844-FLY-MY-UA or email the FAA.

NPA 2021-09 - Regular update of the AMC and GM to Regulation (EU) 2019/947 on the rules and procedures for the operation of unmanned aircraft

The objective of this Notice of Proposed Amendment (NPA) is to maintain a high level of safety for unmanned aircraft system (UAS) operations in the 'open' and 'specific' categories.

This NPA proposes to amend some of the existing, and introduce new, acceptable means of compliance (AMC) and guidance material (GM) to Regulation (EU) 2019/947 on the rules and procedures for the operation of UASs, as follows:

- new AMC and GM for the definition of 'geographical zones';
- revised forms for the application and issue of operational authorisations in the 'specific' category;
- new AMC defining the procedure to be applied by UAS operators and the competent authorities for cross-border operations, including the related forms;
- new AMC and GM for the standard scenarios (STSs);
- new AMC to comply with the mitigations requirements and meet the operational safety objectives (OSOs) that are defined in the specific operations risk assessment (SORA);
- new AMC that provide the syllabus for training modules for remote pilots that operate in the 'specific' category; and
- revision of the AMC following feedback received from national aviation authorities (NAAs) and UAS operators.

In particular, the AMC and GM for the geographical zones are the outcome of the UAS Geographical Zones Task Force (TF) which was established based on the input of the MAB providing procedures and guidelines for Member States (MSs) to create zones in order to protect areas where the safety, security or privacy risk is higher.

Both the amended and the new AMC and GM are expected to maintain safety as regards UAS operations in the 'open' and 'specific' categories, and increase the harmonisation of UAS operations across the European Union by providing a consistent and correct interpretation of the regulatory material.

Cabinet d'Expertise en Aéronautique - Inscrit près la cour d'appel d'Amiens – Indépendant de l'EASA
15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

NAT OPS Bulletin

NAT OPS Bulletins - All Documents (icao.int)

No changes

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IOSA

IATA - IOSA

Related documents can also be found here:

- IOSA Support Program (pdf)
- IOSA Guidance for Safety Monitoring under COVID-19 Ed. 5 (pdf)
- IPM Ed 12 – Temporary Appendix - Revision 2 (pdf)
- ISM Ed 13 - Remote Audit - Revision 1 (pdf)
- IAH P&G Ed 11 - Temporary Appendix Revision 1(pdf)
- IOSA Operator Alert 18 - IPM IAH updates (pdf)

Safety Alerts

Affected Product(s)	Effective Date	Subject and Additional Information
28 and 56-Day NASR Subscriber File, NAV.txt File	September 9, 2021	MISSE NDB (MS) NAVIAD Status. See the 21-12 NASR Safety Alert (PDF) for complete information.
Consumers of SNOWTAMS stored by the United States	September 21, 2021	Effective immediately, until further notice, the United States NOTAM System will not be able to ingest, store, display, and disseminate international SNOWTAMs issued in the new ICAO SNOWTAM format. See the 21-02 USNOF Safety Alert (PDF) for complete information.
28-Day NASR Subscriber File, AWY.txt File	September 21, 2021	The AWY.txt file of the 28-Day Subscription, contains an error in the segments; BUNNS to HERID to LIT. See the 21-16 NASR Safety Alert (PDF) for complete information.

ate Posted	Affected Product(s)	Effective Date	Subject and Additional Information
Sep 23, 2021	**XML (d-TPP_metafile.xml) (2110)**	October 7, 2021	Instrument Approach Procedure records in the XML (d-TPP_Metafile.xml) (2110) had incorrect amendment numbers (amdtnum) and procedural date (amdtdate) values. See the 21-04 TERM Safety Alert (PDF) for complete information.

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15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

ate Posted	Affected Product(s)	Effective Date	Subject and Additional Information
Sep 15, 2021	**NASR 28-Day Subscriber Files, AWY.txt File**	October 7, 2021	GNSS Required text missing for Q29, Q811, Q902. See the 21-15 NASR Safety Alert (PDF) for complete information.
Sep 8, 2021	**NASR 28-Day Subscriber Files, FAA Charts, and NFDD**	October 7, 2021	October 7, 2021 AIRAC Cycle. See the 21-14 NASR Safety Alert (PDF) for complete information.
Aug 23, 2021	**Enroute IFR Charting Products**	October 7, 2021	IFR Charting expanded NAVAID SSV codes. See the 21-01 ENR Charting Notice (PDF) for complete information.
Aug 11, 2021	**Seattle VFR Terminal Area Chart and Digital Visual Charts**	October 7, 2021	The addition of Portland TAC to the Seattle TAC. See the 21-03 VIS Charting Notice (PDF) for complete information.
Sep 21, 2021	**Consumers of SNOWTAMS stored by the United States**	September 21, 2021	Effective immediately, until further notice, the United States NOTAM System will not be able to ingest, store, display, and disseminate international SNOWTAMs issued in the new ICAO SNOWTAM format. See the 21-02 USNOF Safety Alert (PDF) for complete information.
Sep 21, 2021	**28-Day NASR Subscriber File, AWY.txt File**	Oct 7, 2021	The AWY.txt file of the 28-Day Subscription, contains an error in the segments; BUNNS to HERID to LIT. See the 21-16 NASR Safety Alert (PDF) for complete information.

Safety information bulletin

FAA

All Information for Operators (InFOs) (faa.gov)

All Safety Alerts for Operators (SAFOs) (faa.gov)

https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgSAIB.nsf/MainFrame?OpenFrameSet

Issue Date	SAIB Number	Subject
13/09/2021	AIR-21-17	Rotorcraft Bird Strike Protection and Mitigation
16/09/2021	AIR-21-15R1	The FAA received reports in January and February 2020 of ADS-B Out compliant aircraft on which ADS-B Out transmissions were not operating. The cause of this was due to certain avionics power up sequences involving the RMU-855. The crew could be unaware of this issue unless informed of it by Air Traffic Control (ATC). Honeywell has identified different airplanes with this equipment, totaling approximately 2,750 affected airplanes. This condition results in failure to comply with 14 CFR 91.225 and 14 CFR 91.227 when ADS-B Out is disabled and the aircraft operates in the airspace defined in 14 CFR 91.225.

EASA

EASA Safety Publications Tool (europa.eu)

Issue Date	SIB Number	Subject
02/09/2021	AIR-21-16	Textron (Cessna, Reims) 172, 177, 180, 182, 185, 188, 206, 207, 210 and 337 Aeroplanes - Seat Back Attachment Bolt Inspection
02/09/2021	AIR-21-14	Robinson R44 and R66 HeliSAS Autopilot/Garmin Primary Flight Display (PFD) Interface
03/09/2021	SIB 2021-12R1	Use of Aeronautical Terminal Information Service by Air Traffic Services Units to Promulgate Information on Runway Surface Conditions – Global Reporting Format
06/09/2021	SIB 2016-02R1	Use of Erroneous Parameters at Take-off
27/09/2021	SIB 2021-15	Origination and Issuance of SNOWTAM for Promulgating Information on Runway Surface Conditions – Global Reporting Format

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15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

Conflict zone information bulletin

Conflict Zone Information Bulletin (CZIB's) | EASA (europa.eu)

No changes

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Certification Up date

FAA do not need to be followed in this part? due to ECFR – See part Regulation or safety Bulletins for completion.

EASA

- Proposed Special Condition SC-D25.855-01 – Storage Containers in passenger cabin - Issue 1
- Final Deviation ref. DEV-D25.855-01 Rev. 1 on Transportation of cargo in passenger compartments - Issue 3
- Final Equivalent Safety Finding ref. ESF-F25.1389-01 on Position lighting system with protective tape in the lens – minimum intensities - Issue 01
- Final Special Condition SC-B22.151-01 - sustainer assisted aerotow - Issue 01
- Final Deviation: Collins Aerospace "Population 2" Hoist System Installation - Issue 01
- Proposed ESF ref. ESF-FCD.425-01 on CS-FCD T3 Evaluation Process: Issue 01
- Proposed Certification Memorandum CM 21.A-A-002 Parts Detached from Rotorcraft - Issue 1

AMC & GM Part-21 — Issue 2, Amendment 5

Implementation of CAEP/9 amendments

Master MEL-OSD

MMEL

EMB-545-550_Rev_5

Document Title:	MMEL BH-212/412 Rev 10, Bell Textron Inc., 212, 412, 412CF, 412EP (H4SW)
Summary:	Outlines the Master Minimum Equipment requirements and procedures for Bell Textron Inc. rotorcraft models 212, 412, 412CF, and 412EP. Provides lists/tables and resources for use by inspectors, pilots, technicians, and others in the field and public sector.
Documents for Download:	Draft Document (PDF) Draft Document Comment Grid (MS Word)
Reference:	***Title 14 of the Code of Federal Regulations (14 CFR)*** • Part 91, General Operating and Flight Rules • Part 121, Operating Requirements: Domestic, Flag, and Supplemental Operations • Part 125, Certification and Operations: Airplanes Having A Seating Capacity of 20 or More Passengers or A Maximum Payload Capacity of 6,000 Pounds or More; and Rules Governing Persons On Board Such Aircraft • Part 129, Operations: Foreign Air Carriers and Foreign Operators of U.S.-Registered Aircraft Engaged In Common Carriage • Part 135, Operating Requirements: Commuter and On Demand Operations and Rules Governing Persons On Board Such Aircraft. MMEL Policy Letter PL-25, MMEL and MEL Definitions MMEL Policy Letter PL-34, MMEL and MEL Preamble MMEL Policy Letter PL-36, FAR Part 91 MEL Approval & Preamble
Comments Due:	October 7, 2021
How to Comment:	**Deliver comments by mail or hand to:** Colin A. Cook 600 Maryland Ave SW

Document Title:	MMEL BH-212/412 Rev 10, Bell Textron Inc., 212, 412, 412CF, 412EP (H4SW)
	Suite 610E Washington, DC 20024 **Email comments to:** Email Comments

Document Title:	MMEL G-IV Rev 12, Gulfstream Aerospace, GIV, (G300), (G400)
Summary:	This Master Minimum Equipment List (MMEL) outlines the requirements and procedures for the Gulfstream Aerospace Corporation (GAC) G IV (G 300) (G 400) series aircraft. This MMEL provides lists/tables and resources for use by inspectors, pilots, technicians, in the field and the public sector.
Documents for Download:	Draft Document (PDF) Draft Document Comment Grid (MS Word)
Reference:	***Title 14 of the Code of Federal Regulations (14 CFR)*** • Part 91, General Operating and Flight Rules • Part 125, Certification and Operations: Airplanes Having A Seating Capacity of 20 or More Passengers or A Maximum Payload Capacity of 6,000 Pounds or More; and Rules Governing Persons On Board Such Aircraft • Part 135, Operating Requirements: Commuter and On Demand Operations and Rules Governing Persons On Board Such Aircraft. MMEL Policy Letter PL-25, MMEL and MEL Definitions MMEL Policy Letter PL-34, MMEL and MEL Preamble MMEL Policy Letter PL-36, FAR Part 91 MEL Approval & Preamble MMEL Policy Letter PL-119, Two-Section MMELs (Parts 91, 125, and 135).
Comments Due:	October 18, 2021

Document Title:	MMEL G-IV Rev 12, Gulfstream Aerospace, GIV, (G300), (G400)
How to Comment:	**Deliver comments by mail or hand to:** Colin A. Cook 600 Maryland Ave SW Suite 610E Washington, DC 20024 **Email comments to:** Email Comments

Document Title:	MMEL G-280 Rev 4, Gulfstream Aerospace, Gulfstream G280
Summary:	Outlines the Master Minimum Equipment requirements and procedures for Gulfstream G280 aircraft. Provides lists/tables and resources for use by inspectors, pilots, technicians, and others in the field and public sector.
Documents for Download:	Draft Document (PDF) Draft Document Comment Grid (MS Word)
Reference:	**Title 14 of the Code of Federal Regulations (14 CFR)** • Part 91, General Operating and Flight Rules • Part 121, Operating Requirements: Domestic, Flag, and Supplemental Operations • Part 125, Certification and Operations: Airplanes Having A Seating Capacity of 20 or More Passengers or A Maximum Payload Capacity of 6,000 Pounds or More; and Rules Governing Persons On Board Such Aircraft • Part 129, Operations: Foreign Air Carriers and Foreign Operators of U.S.-Registered Aircraft Engaged In Common Carriage • Part 135, Operating Requirements: Commuter and On Demand Operations and Rules Governing Persons On Board Such Aircraft.

Document Title:	MMEL G-280 Rev 4, Gulfstream Aerospace, Gulfstream G280
	MMEL Policy Letter PL-25, MMEL and MEL Definitions MMEL Policy Letter PL-34, MMEL and MEL Preamble MMEL Policy Letter PL-36, FAR Part 91 MEL Approval & Preamble MMEL Policy Letter PL-119, Two-Section MMELs (Parts 91, 125, and 135).
Comments Due:	September 10, 2021
How to Comment:	**Deliver comments by mail or hand to:** Colin A. Cook 600 Maryland Ave SW Suite 610E Washington, DC 20024 **Email comments to:** Email Comments

Document Title:	MMEL S-70M Rev 0, Sikorsky Aircraft Corporation, S-70M (TCDS H5NE)
Summary:	Outlines the Master Minimum Equipment requirements and procedures for Sikorsky Aircraft Corporation model S-70M. Provides lists/tables and resources for use by inspectors, pilots, technicians, and others in the field and public sector.
Documents for Download:	Draft Document (PDF) Draft Document Comment Grid (MS Word)
Reference:	**Title 14 of the Code of Federal Regulations (14 CFR)** • Part 91, General Operating and Flight Rules • Part 121, Operating Requirements: Domestic, Flag, and Supplemental Operations • Part 125, Certification and Operations: Airplanes Having A Seating Capacity of 20 or More Passengers or A Maximum Payload Capacity of 6,000 Pounds or More; and Rules Governing Persons On Board Such Aircraft

Document Title:	MMEL S-70M Rev 0, Sikorsky Aircraft Corporation, S-70M (TCDS H5NE)
	• Part 129, Operations: Foreign Air Carriers and Foreign Operators of U.S.-Registered Aircraft Engaged In Common Carriage • Part 135, Operating Requirements: Commuter and On Demand Operations and Rules Governing Persons On Board Such Aircraft. MMEL Policy Letter PL-25, MMEL and MEL Definitions MMEL Policy Letter PL-34, MMEL and MEL Preamble MMEL Policy Letter PL-36, FAR Part 91 MEL Approval & Preamble
Comments Due:	September 13, 2021
How to Comment:	**Deliver comments by mail or hand to:** Colin A. Cook 600 Maryland Ave SW Suite 610E Washington, DC 20024 **Email comments to:** Email Comments

Document Title:	MMEL BH-212/412 Rev 10, Bell Textron Inc., 212, 412, 412CF, 412EP (H4SW)
Summary:	Outlines the Master Minimum Equipment requirements and procedures for Bell Textron Inc. rotorcraft models 212, 412, 412CF, and 412EP. Provides lists/tables and resources for use by inspectors, pilots, technicians, and others in the field and public sector.
Documents for Download:	Draft Document (PDF) Draft Document Comment Grid (MS Word)
Reference:	**Title 14 of the Code of Federal Regulations (14 CFR)** • Part 91, General Operating and Flight Rules • Part 121, Operating Requirements: Domestic, Flag, and Supplemental Operations

Document Title:	MMEL BH-212/412 Rev 10, Bell Textron Inc., 212, 412, 412CF, 412EP (H4SW)
	• Part 125, Certification and Operations: Airplanes Having A Seating Capacity of 20 or More Passengers or A Maximum Payload Capacity of 6,000 Pounds or More; and Rules Governing Persons On Board Such Aircraft • Part 129, Operations: Foreign Air Carriers and Foreign Operators of U.S.-Registered Aircraft Engaged In Common Carriage • Part 135, Operating Requirements: Commuter and On Demand Operations and Rules Governing Persons On Board Such Aircraft. MMEL Policy Letter PL-25, MMEL and MEL Definitions MMEL Policy Letter PL-34, MMEL and MEL Preamble MMEL Policy Letter PL-36, FAR Part 91 MEL Approval & Preamble
Comments Due:	October 7, 2021
How to Comment:	**Deliver comments by mail or hand to:** Colin A. Cook 600 Maryland Ave SW Suite 610E Washington, DC 20024 **Email comments to:** Email Comments

OSD – FSBR

Operational Evaluation Guidance Material (OE GM) / Operational Evaluation Reports (OEB) / Operational Suitability Data (OSD) | EASA (europa.eu)

FAA Safety Briefing

Service Bulletins and the Aircraft Owner

Manufacturers issue aircraft Service Bulletins to inform owners and operators about critical and useful information on aircraft safety, maintenance, or product improvement. Compliance with Service Bulletins may or may not be mandatory, but you should never ignore them when it comes to safety.

Are Service Bulletins Mandatory?

The short answer is — it depends. If you are operating your aircraft under 14 CFR part 91, a service bulletin is advisory, and compliance is not mandatory unless it is included in an Airworthiness Directive. Keep in mind that even when a service bulletin is not mandatory, you should always pay attention to it as a means to ensure your safety. Let's unpack this further.

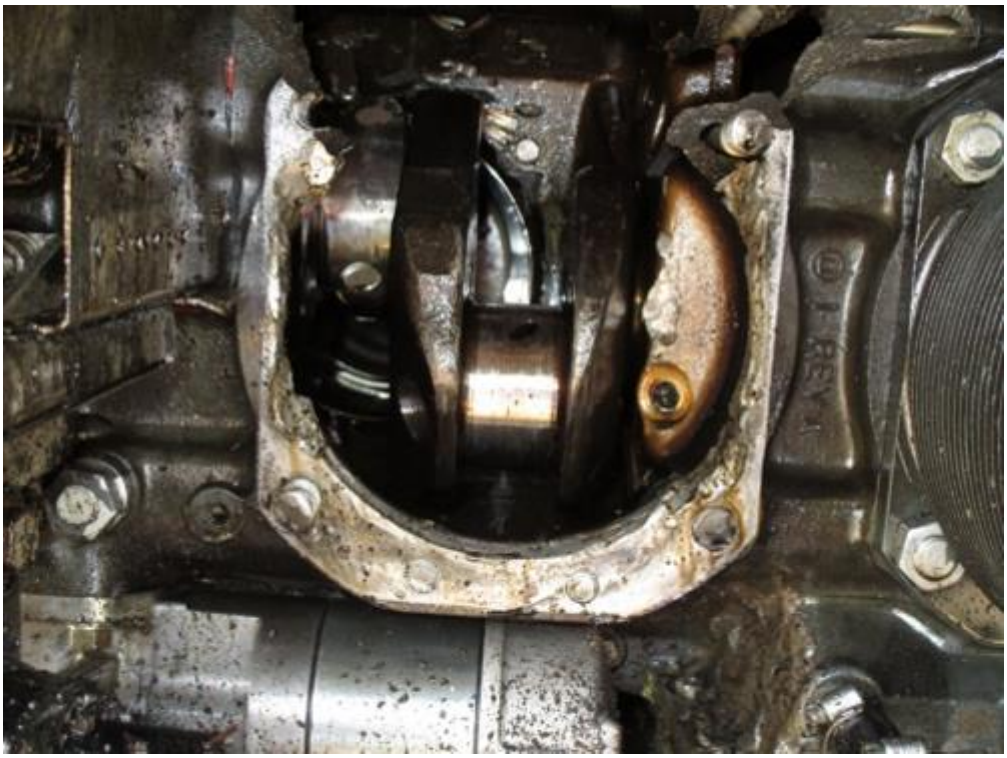
Are Service Bulletins the Same as Airworthiness Directives?

No. The FAA issues Airworthiness Directives (AD) and aircraft manufacturers issue Service Bulletins (SB). ADs are legally enforceable regulations, in accordance with 14 CFR part 39, to correct an unsafe condition that exists in a product. Compliance with an AD is mandatory for continued airworthiness.

Manufacturers issue aircraft Service Bulletins in response to identified maintenance and manufacturing defect issues to give owners and operators critical and useful information about aircraft safety, maintenance, or product improvement. Compliance may or may not be required depending on the type of operation and whether or not it is included in an AD.

If Service Bulletins Are Not Mandatory, Can I Ignore Them?

No. Manufacturers issue SBs to call attention to improvements you should make to enhance your safety. It is also just good sense to heed the advice of the aircraft manufacturer who is providing important information about your aircraft.



Service Bulletins:

1) Inform you about the manufacturer's recommended inspection and maintenance items for your aircraft.

2) Help you detect trends and spot weaknesses.

3) Advise you about items that may be wearing faster than anticipated or items that you or your mechanic might overlook.

When a SB displays the words "Mandatory," "Alert," or "Emergency" in big red letters, it is emphasizing a significant safety concern, and manufacturers may ask the FAA to issue a specific AD to address the unsafe condition. These mandatory SBs can also get included in an AD as an additional source of information about the unsafe condition. If a SB is included in an AD, then compliance with that SB is mandatory for continued airworthiness.

However, do not ignore "recommended" or "optional" SBs. Take note and ask your mechanic to check these items during inspection.

Service Bulletins call attention to improvements you should make to enhance your safety. Do not ignore them.

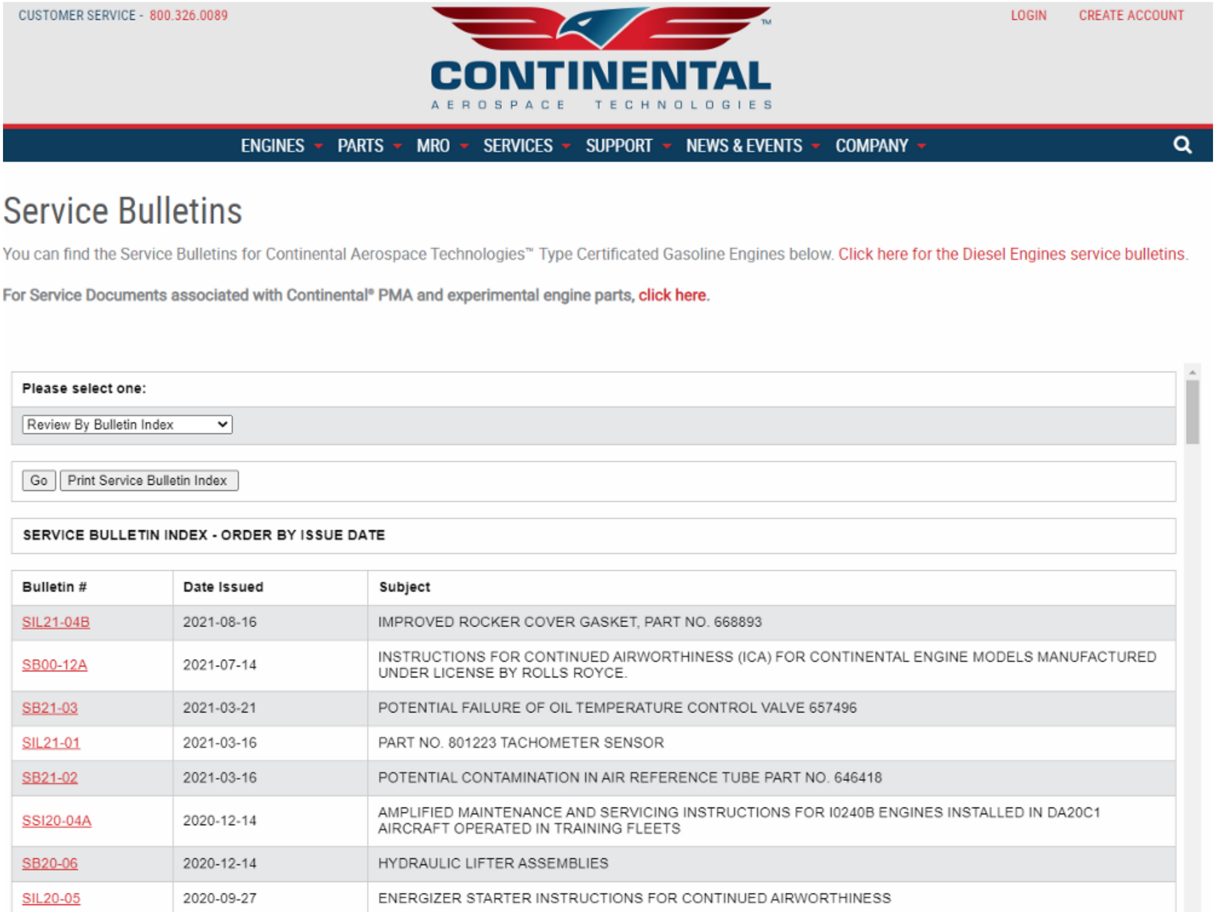
Make it a best practice to read, or ask your mechanic to review, any SB that the manufacturer issues for your aircraft. If cost is a concern, discuss this with your mechanic to determine the best course of action. The SB may only be reporting a product improvement that does not affect airworthiness or your safety.

Here's What Can Happen If You Ignore a Service Bulletin

On July 7, 2017, a Cessna T337 with faulty fuel gauges crashed in a wooded area after running out of fuel. Textron Aviation published a mandatory SB that required inspection of the fuel quantity indicating system to verify that each fuel gauge showed the precise fuel amount. It also required an initial inspection within 100 hours of operation and subsequent recurring inspections every 12 months. Examination of the airplane's maintenance logbooks revealed no evidence of compliance with the mandatory SB. The aircraft was a total loss. Fortunately, the pilot and passenger survived with minor injuries, but it could have been much worse. They learned an expensive lesson about the importance of SBs.

Where Can I Find Service Bulletins For My Aircraft?

SBs are available online, and they are free. Take a look at any engine or airframe manufacturer's website and you'll find up to date information on the safety issues identified from accident reports, service difficulty reports, and any other data used for safety analysis and product improvement.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Service Bulletins

You can find the Service Bulletins for Continental Aerospace Technologies™ Type Certificated Gasoline Engines below. Click here for the Diesel Engines service bulletins.

For Service Documents associated with Continental® PMA and experimental engine parts, click here.

Please select one:

Review By Bulletin Index

Go Print Service Bulletin Index

SERVICE BULLETIN INDEX - ORDER BY ISSUE DATE

Bulletin #	Date Issued	Subject
SIL21-04B	2021-08-16	IMPROVED ROCKER COVER GASKET, PART NO. 668893
SB00-12A	2021-07-14	INSTRUCTIONS FOR CONTINUED AIRWORTHINESS (ICA) FOR CONTINENTAL ENGINE MODELS MANUFACTURED UNDER LICENSE BY ROLLS ROYCE.
SB21-03	2021-03-21	POTENTIAL FAILURE OF OIL TEMPERATURE CONTROL VALVE 657496
SIL21-01	2021-03-16	PART NO. 801223 TACHOMETER SENSOR
SB21-02	2021-03-16	POTENTIAL CONTAMINATION IN AIR REFERENCE TUBE PART NO. 646418
SSI20-04A	2020-12-14	AMPLIFIED MAINTENANCE AND SERVICING INSTRUCTIONS FOR I0240B ENGINES INSTALLED IN DA20C1 AIRCRAFT OPERATED IN TRAINING FLEETS
SB20-06	2020-12-14	HYDRAULIC LIFTER ASSEMBLIES
SIL20-05	2020-09-27	ENERGIZER STARTER INSTRUCTIONS FOR CONTINUED AIRWORTHINESS

You can also find information, guidance, recommendations, and airworthiness concerns for your aircraft free of charge in the FAA's Special Airworthiness Information Bulletin (SAIB) database. It is searchable by SAIB number or by aircraft make and model. Subscribe and get the latest ADs and SAIBs delivered straight to your inbox.

Service Bulletins are a great way to stay informed about product improvements and safety issues that affect your aircraft. Take an active role in maintenance by reviewing inspection results and discussing ADs and SBs with your mechanic.

Watch Service Bulletins in 57 Seconds

https://www.youtube.com/watch?v=HOUVwHMc6Zw&list=PL5vHkqHi51DQdF_PXKQT7uJUPd4UzlxNS&index=1

Publications

Recherche : NEWS (icao.int)

News & Updates (faa.gov)

Newsroom & Events | EASA (europa.eu)

Greening European ATM's ground infrastructure: What could ANSPs achieve over the next decade?

We would like to share with you our latest EUROCONTROL Think Paper, which argues that there is considerable potential to 'green' the ground infrastructure of European air traffic management over the next decade.

We conduct the very first assessment of the extent of this infrastructure, which includes well over 6,000 communications, navigation and surveillance ground-based facilities across Europe, as well as over 400 control towers, over 60 area control centres, and various offices. After modelling the total predicted energy consumption of this infrastructure, we then calculate the CO2 equivalent (CO2e) emissions that would be produced as a result.

Our research suggests that if air navigation service providers could make the switch to renewable energy, and seize the right moment over the next decade in their investment cycles to replace energy-inefficient equipment, over 311K tonnes CO2e could be saved on an annual basis, summing up to a sizeable 6.2+ million tonnes by 2050.

Progressively decarbonising European ATM's ground infrastructure is, we argue, both realistic and achievable, and could deliver large potential emissions savings on an annual basis in support of aviation's overall decarbonisation goals.

See attached

The air transport monthly monitor

The air transport industry is not only a vital engine of global socio-economic growth, but it is also of vital importance as a catalyst for economic development. Not only does the industry create direct and indirect employment and support tourism and local businesses, but it also stimulates foreign investment and international trade.

Informed decision-making is the foundation upon which successful businesses are built. In a fast-growing industry like aviation, planners and investors require the most comprehensive, up-to-date, and reliable data. ICAO's aviation data/statistics programme provides accurate, reliable and consistent aviation data so that States, international organizations, the aviation industry, tourism and other stakeholders can:

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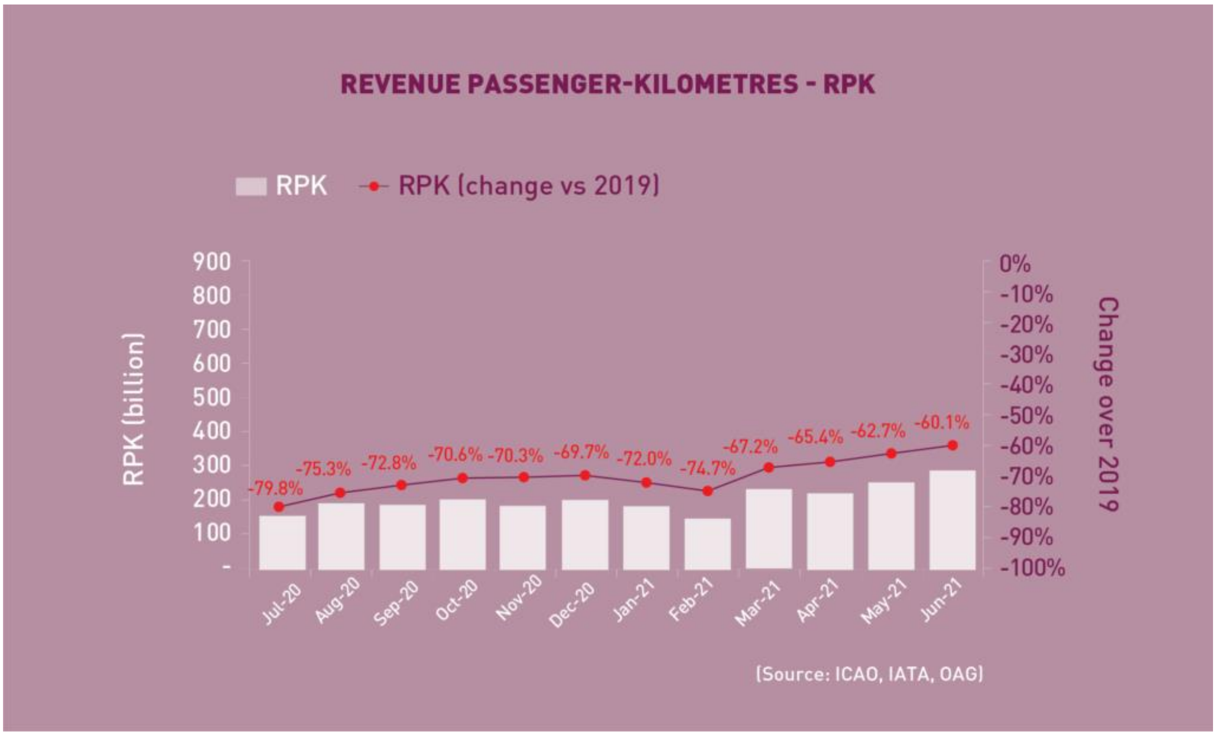
15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

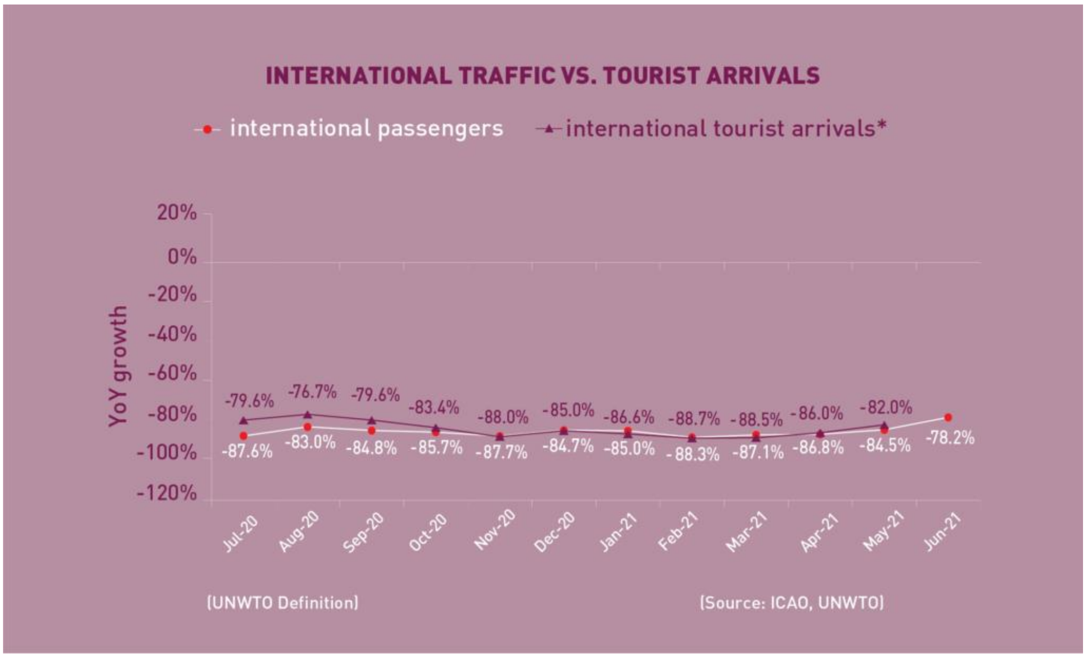
- make better projections;
- control costs and risks;
- improve business valuations; and
- benchmark performance.

The UN recognized ICAO as the central agency responsible for the collection, analysis, publication, standardization, improvement and dissemination of statistics pertaining to civil aviation. Because of its status as a UN specialized agency, ICAO remains independent from outside influences and is committed to consistently offering comprehensive and objective data. Every month ICAO produces this Air Transport Monitor, a monthly snapshot and analysis of the economic and aviation indicators.



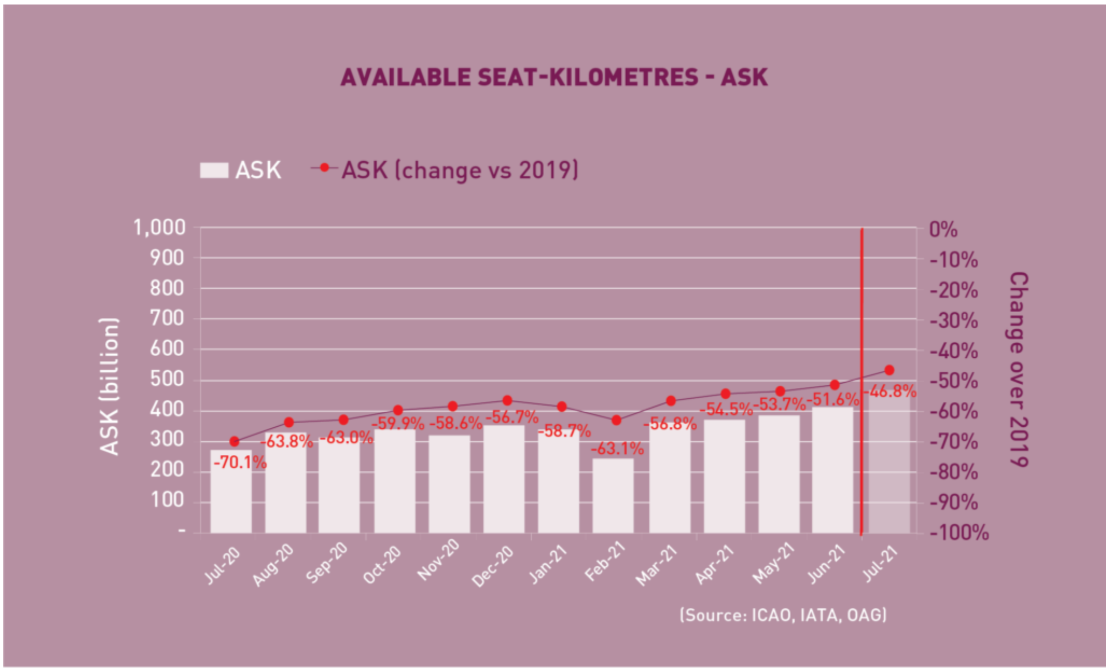
Revenue Passenger-Kilometres – RPK

World passenger traffic fell by -60.1% in June 2021 (compared to 2019), +2.6 percentage points up from the decline in the previous month. Although the traditional demand driver – economic activity – has been showing an upward trend, air travel continued to be largely affected by the rising COVID-19 cases and strict travel restrictions amid the spread of new variants. Overall, for the first half of 2021, passenger traffic remained at more than -60% below the 2019 levels, with the Middle East and Europe recording the weakest performance.



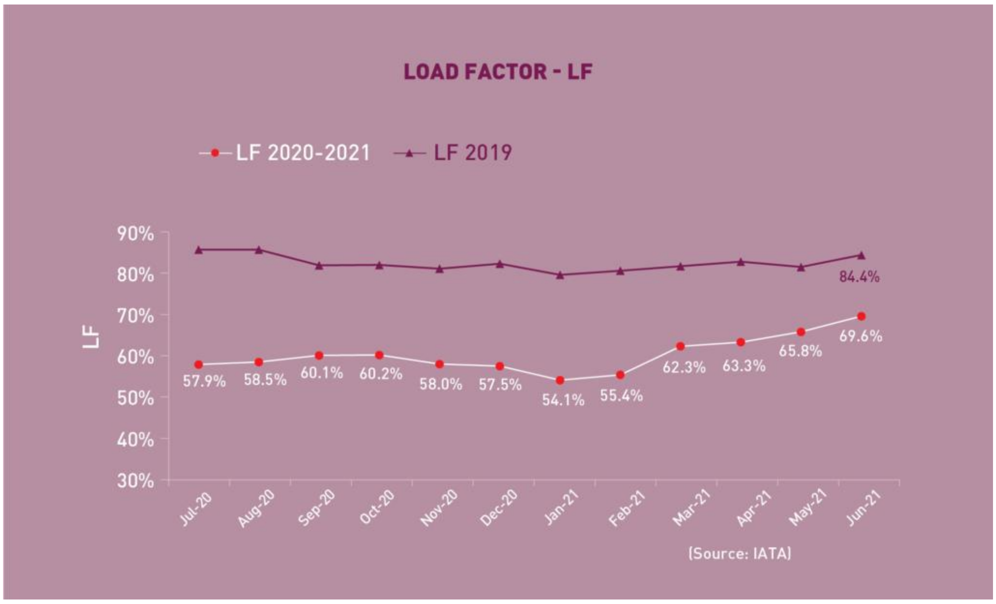
International Traffic vs. Tourist Arrivals

International passenger numbers fell by -78.2% in June 2021 (compared to 2019), +6.3 percentage points up from the decline in the previous month. Cross-border travel restrictions continued to weigh heavily on international travel demand. As a result, international traffic for the first half of 2021 was far below 2019 levels. The international tourist arrivals also remained stagnant and followed a similar trend as international passenger traffic.



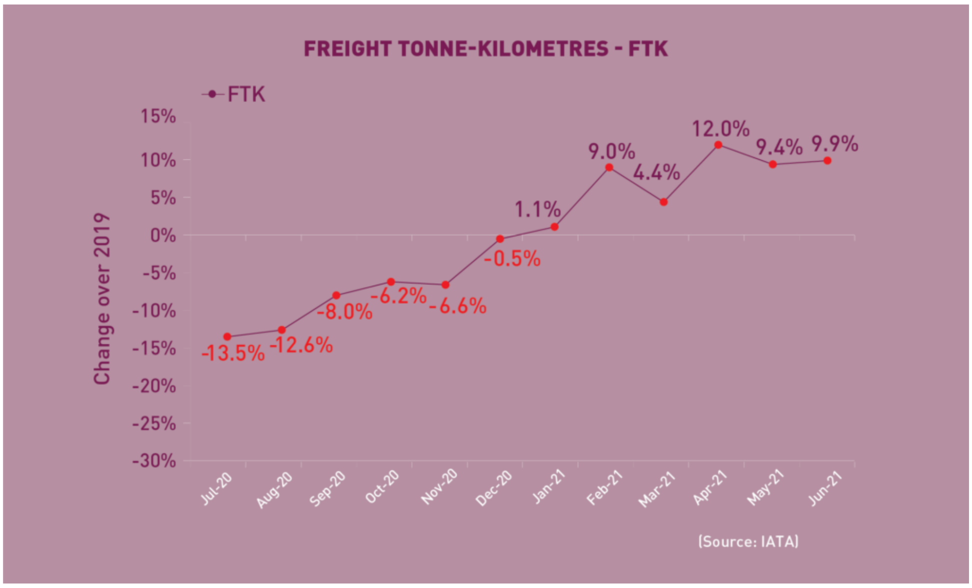
Available Seat-Kilometres – ASK

Capacity worldwide fell by -51.6% in June 2021 (compared to 2019), +2.1 percentage points up from the decline in the previous month (-53.7%). As air travel continues to recover, capacity is expected to increase in July 2021 to -46.8% down from the 2019 levels.



Load Factor

The passenger Load Factor reached 69.6% in June 2021, +3.8 percentage points higher than the previous month. The domestic load factor continued to show solid performance and returned to a little less than 80%. As the recovery of capacity was faster than travel demand recovery, the June LF remained significantly below 2019 levels at -14.8 percentage points lower.



Freight Traffic

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Freight Tonne-Kilometres – FTK

World freight traffic reported a growth of +9.9% in June 2021 (compared to 2019), +0.5 percentage point higher than the growth in the previous month. Air cargo sustained its strong growth supported by the continued increase in trade and manufacturing. Demand for air cargo is likely to further grow underpinned by the global economic recovery. Performance was mixed across regions. All regions, except for Latin America/Caribbean, have returned to pre-pandemic traffic levels. While Africa, North America, and the Middle East have shown double-digit growth, Asia/Pacific and Europe grew modestly. Overall, for the first half of 2021, air cargo was +8.0% above the 2019 levels.

Replays of the Airbus Summit 2021

Airbus Summit 2021 - Events - Airbus

EASA signs Working Arrangement with India

EASA and the Directorate General of Civil Aviation of India (DGCA India) have signed a Working Arrangement to strengthen their relationship and to achieve common safety and environmental protection standards. The agreement aims at promoting cooperation, the understanding of each other's regulatory systems and facilitating the exchange of aeronautical products, services and personnel.

This agreement is the result of intensive negotiations between the two parties over several years and marks an important milestone in strengthening the relationship between India and Europe in the aviation world.

Through this Working Arrangement, the parties intend to develop closer collaboration in the following domains:

- Rulemaking cooperation, including sharing of information and best practices, in order to support the implementation of harmonised aviation safety and environmental protection requirements.
- Facilitate issuance or acceptance of certificates for products, parts and appliances
- Sharing of safety information, including co-operation on continued airworthiness of in-service products, parts and appliances accepted or approved in application of the Working Arrangement;
- Technical training and professional staff development.

EUROCONTROL DATA SNAPSHOT

In a recent snapshot we explored how flights have recovered at different rates in different countries. Another source of variation is in the types of aircraft seen, which is represented in this chart by changes in average weight. These weight changes tell a story about the balance between long-haul and short-haul, and between cargo and passenger flights.

Heavier aircraft also mean higher revenues for air navigation service providers. Weights were very high between March and June 2020 (see spike in chart). This partly made up for the revenues lost due to cuts in flights, although in most cases it only marginally reduced the financial impact due to the substantial decline

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in flights. In early 2021, many countries saw average aircraft weights 20-50 tonnes higher than in the same period in 2019. (In normal times, a change of around 2 tonnes between one year and another would be more usual.) Now that weight gain is coming to an end.

Estonia has seen large weight gains for much of 2021, with its Baltic neighbours in a similar position. This reflects the continuing strength of cargo overflights (25% above August 2019), compared to total flights (down by 50%). So this shows both the strength of long-haul cargo (to Russia and to North and East Asia), and the rarity of passenger flights to the same destination. With the Summer's traffic recovery, the weight gain has diminished.

In contrast, Bulgaria and some of its neighbours have seen little increase in weight compared to 2019. Flows of long-haul, heavy aircraft to the Middle East and South-East Asia, especially from the UK, are weak. And still, in the last months, average weights have declined, cancelling out some of the revenue benefits from the recovery in flight numbers.

Norway has been seen in several snapshots as an outlier, with its strong domestic flows. This is reflected also in the average aircraft being lighter for most of the period (few of the heavy long-haul aircraft, relatively more lighter, short-haul aircraft). Finally in the chart, the Netherlands stands for the many countries which had much heavier aircraft last winter, but where the mix of aircraft is closer to normal this Summer.

See attached

ICAO eLibrary

To support the recovery of global aviation from the impacts of COVID-19, ICAO has released the second edition of the Testing and Cross-border Risk Management Measures Manual. With information about the public health corridors (PHCs), the latest scientific developments in testing, plus an additional section devoted to vaccination, this manual will guide you towards a successful recovery for air transportation. The manual is available in English, Arabic, Chinese, Russian and Spanish.

To get the latest on this and other ICAO documents and publications, be sure to visit our ICAO eLibrary. Subscription is free, and it comes with useful features* that allow you to cite, highlight, bookmark, share, and more. Create an account and start reading ICAO Publications.

* All eLibrary features are available free of charge for a limited time only. Charges may be applied in the future.

Unruly Passenger Rate Drops, But Remains Too High

WASHINGTON — The rate of unruly passenger incidents on commercial flights has dropped sharply since the Federal Aviation Administration (FAA) launched its Zero Tolerance campaign but the rate remains too high, according to new data released today.

"Our work is having an impact and the trend is moving in the right direction. But we need the progress to continue. This remains a serious safety threat, and one incident is one too many," said FAA Administrator Steve Dickson. "The FAA will continue its Zero Tolerance policy, keep its public awareness campaign going, and keep pushing and partnering with everyone in the aviation system to do more. We appreciate the tremendous work of all our partners in the airline, airport, labor, and law enforcement communities."

As of last week, unruly passenger incidents were occurring approximately six times per every 10,000 flights. That's an approximately 50 percent drop from early 2021, but it's more than twice as high as the end of 2020. Since the FAA launched its public awareness campaign with memes and two public service announcements, the rate has fallen approximately 30 percent. View a graphic with the data.

Using its full legal authority to deter this dangerous behavior, the FAA adopted a zero-tolerance policy toward unruly passengers in January 2021. Under this policy, the FAA no longer issues warning letters. Instead, it moves directly to fines, which have totaled $1.1 million to date. In addition to its public service announcement videos and memes, the agency has asked airports to help educate passengers that they cannot consume alcohol on board that they purchase at restaurants and shops in the airport or that is not served by a flight attendant.

Later this month, the FAA plans to host unruly-passenger working sessions with key aviation stakeholders. The FAA will ask members of the aviation system to share best practices and to identify additional steps they and the U.S. government can take to reduce the unruly incident rate further.

Detailed current data on these incidents is available on our unruly passenger website. Press releases about individual cases, and the work the FAA has done to get the word out about the consequences passengers face, is available in our unruly passenger toolkit

ICAO

We are pleased to inform you that the following titles have been published on ICAO.

Sl No	Code	Title	Type	Edition	Descriptions
1	978-92-9265-263-0	Doc 10152 - دليل تدابير الاختبار وإدارة المخاطر عبر الحدود	Security and Facilitation	2	Click Here
2	978-92-9265-554-9	Doc 10152 - 检测和跨境风险管理措施手册	Security and Facilitation	2	Click Here
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		безопасности полетов, связанными с COVID-19			
21	10144-3	Doc 10144 — Manuel à l'intention des AAC sur la gestion des risques en matière de sécurité de l'aviation relatifs à la COVID-19	Safety	1	Click Here
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38	10148-4	Doc 10148 — Manual de instrucción periódica de la tripulación de cabina durante la COVID-19	Safety	1	Click Here
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40	10148-6	Doc 10148 — كُتيّب التدريب المتكرر لطاقم مقصورة الركاب أثناء جائحة فيروس كورونا	Safety	1	Click Here
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42	978-92-9265-484-9	Circular 357 - Инструктивные указания по представлению членами летных и кабинных экипажей информации о торговле людьми	Safety		Click Here
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FAA Invests $42 Million in Airports across Alaska

Part of the FAA's campaign to increase safety in Alaska

WASHINGTON – The U.S. Department of Transportation's Federal Aviation Administration (FAA) will award seven Alaska airports a total of $42 million in Airport Improvement Program grants to help with safety, access and sustainability efforts. The FAA has awarded more than 64 grants totaling $257.4 million to Alaska airports during fiscal year 2021.

"These grants reflect our ongoing commitment to the unique needs of Alaska aviation community and our focus on supporting the extensive Alaska National Airspace System," said FAA Administrator Steve Dickson.

Aviation provides the backbone of daily commerce to many communities in the state, including the delivery of food and life-saving supplies, inter-city and inter-village transportation, emergency medical evacuations and daily commuting. Approximately 82 percent of communities in Alaska are only accessible by air. Many of these communities are home to Alaska natives, which represent nearly 20 percent of the state's population.

"Transportation connectivity is paramount to reach communities throughout our great nation. These grants are key to achieve that goal," said Arlando Teller, Deputy Assistant Secretary for Tribal Affairs.

The projects announced today will not have to pay the usual local match thanks to nearly $100 million in President Biden's American Rescue Plan Act.

Today's grants include:

Bethel Census Area

- Bethel Airport in Bethel, Alaska: an additional $6.0 million to the $34.3 million announced in August to replace the airport lighting vault, reconstruct airfield guidance signs, strengthen Runway 01L/19R, rehabilitate the taxiway, and purchase snow removal equipment and an emergency generator.
- Chefornak Airport in Chefornak, Alaska: $6.6 million to rehabilitate the access road to the airport, the airport's runway and the apron area where planes park.
- Kipnuk Airport, Kipnuk, Alaska: $18.9 million for improvements to navigational aids, which include installing new aids as well as the reconstruction of the airport beacon and taxiway lighting. In addition, the airport will use grant funding to widen the runway and rehabilitate the taxiway and apron where planes park.

Kenai Peninsula Borough

- Kenai Municipal Airport, Kenai, Alaska: $506,500 to construct, extend and improve the airport safety area.

Matanuska-Susitna Borough

- Warren "Bud" Woods Palmer Municipal Airport, Palmer, Alaska: $526,000 to improve airport drainage and erosion control for the taxiway.

North Slope Borough

- Atqasuk Edward Burnell Sr. Memorial Airport, Atqasuk, Alaska: add an additional $3.1 million to the $20.7 million announced in August to install navigational aids, including apron edge lights and flood lighting, reconstruct runway and taxiway lighting, replace the airport lighting vault, install additional perimeter fencing, and rehabilitate the airport's runway, taxiway, and apron where planes park. Atqasuk, a remote community in northern Alaska, is solely dependent on aviation for the transportation of people, goods, and critical services.

Prince of Wales-Hyder Census Area

- Metlakatla Airport, Metlakatla, Alaska: $6.5 million to repair the seaplane base so it can be used to safely transport goods and services to remote communities in Alaska, including the Metlakatla Indian Community on Annette Island in southern Alaska.

The funding is from the sixth round of fiscal year 2021 Airport Improvement Program grants.

The Airport Improvement Program receives approximately $3.2 billion in funding each year. A complete listing of grants (PDF) and AIP Grants Data by State is on the FAA website.

FAA Invites Public to Comment on Draft Environmental Review of SpaceX Starship/Super Heavy Program

WASHINGTON-The U.S. Department of Transportation's Federal Aviation Administration (FAA) today invited the public to provide its input on the draft environmental review for the proposed SpaceX Starship/Super Heavy program in Boca Chica, Texas.

The draft document, formally called a Draft Programmatic Environmental Assessment (PEA), evaluates the potential environmental impacts of SpaceX's initial mission profile for the program, including launch and reentry. It also reviews debris recovery, the integration tower and other launch-related construction, and local road closures in Boca Chica, among other issues.

The FAA plans to hold virtual public hearings on Oct. 6 and 7 as part of the 30-day public comment period that ends on Oct. 18, 2021.

SpaceX cannot launch the Starship/Super Heavy vehicle until the FAA completes its licensing process, which includes the environmental review and other safety and financial responsibility requirements. The proposed Starship/Super Heavy operations fall outside of the scope of the existing 2014 Final Environmental Impact Statement (EIS) and Record of Decision for the Boca Chica launch site and requires this additional environmental review under the National Environmental Policy Act.

If the Draft PEA is finalized, and SpaceX further develops the program, the FAA would analyze the environmental impacts of proposed future activities in part by using information developed during the current process.

If the FAA determines the potential environmental impacts of the proposed project would be significant based upon the Draft PEA and a review of the public comments, and those impacts could not be properly mitigated to less-than-significant levels, the agency would conduct a more intensive EIS.

Several federal and state agencies are involved in the Draft PEA as cooperating and participating agencies, including: National Aeronautics and Space Administration, National Park Service, U.S. Coast Guard, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, Texas Parks and Wildlife Department, Texas Historical Commission, Texas Government Land Office and Texas Department of Transportation.

FAA Drone Safety Awareness Week Starts Today

Safely integrating drones into the National Airspace System is a key priority for the Federal Aviation Administration (FAA), and our third-annual Drone Safety Awareness Week helps ensure drone operators understand that they are pilots who must fly safely.

As part of the agency's education efforts, FAA Administrator Steve Dickson will participate in an Instagram Live event with Keith Rosentreter, owner of Alien Drones YouTube Channel, Eno Umoh, Co-Founder Global Air Drone Academy, and Dawn Zoldi, president of UAS Colorado. They will discuss The

Recreational UAS Safety Test (TRUST), how to properly register and mark your drone, the importance of joining a community of drone operators, and how drones are used in science, technology, engineering, and mathematics (STEM) to inspire young people. The event will take place on Wednesday from 1:00-1:30 p.m. EDT.

The week also will feature drone pilots, recreational flyers, and experts discussing their commitment to safety, and sharing tips and information. Several organizations and FAA Safety Team (FAAST) volunteers are hosting virtual events to engage and educate the public about drone safety. If you are new to the drone community, this is a great opportunity to understand how to fly safely.

Each day of the week is dedicated to a specific educational theme:

- Monday: Safe Flyers Take The Recreational UAS Safety Test (TRUST)
- Tuesday: Register and Mark Your Drone
- Wednesday: Become a Part of a Flying Community
- Thursday: New Rules – Remote Identification and Operations Over People
- Friday: Public Safety & Public Acceptance
- Saturday and Sunday: Share the Skies – Get Out and Fly

Please tag your social media stories with #DroneWeek to let us know you're participating in National Drone Safety Awareness Week.

FAA Awards $100M to Develop Next Generation of Sustainable Aircraft Technology

WASHINGTON –The U.S. Department of Transportation's Federal Aviation Administration (FAA) has awarded more than $100 million for companies to help develop technologies that reduce fuel use, emissions and noise. The award is part of a series of steps President Biden is taking to coordinate leadership and innovation across the federal government, aircraft manufacturers, airlines, fuel producers and more to position American aviation to soar towards net zero emissions by 2050. This FAA announcement is part of those efforts.

"Across the country, communities have been devastated by the effects of climate change – but, if we act now, we can ensure that aviation plays a central role in the solution," said Transportation Secretary Pete Buttigieg. "These awards will help America lead the world in sustainable aviation."

The Continuous Lower Energy, Emissions and Noise (CLEEN) Program is a public-private partnership that began in 2010 and is a key part the FAA's overall strategy to tackle the global challenge of climate change and lower the impact aviation has on communities. The program requires the companies receiving the contracts to match or exceed the FAA's investment, bringing the total to at least $200 million over a five-year period. The awards are the third phase of the FAA's CLEEN program.

FAA Investment

Under CLEEN Phase III, the FAA and six industry partners will focus on reducing aviation emissions and noise, including pursuing goals of reducing carbon dioxide (CO2) emissions by improving fuel efficiency by at least 20 percent below the relevant International Civil Aviation Organization (ICAO) standard; NOx emissions by 70 percent relative to the most recent ICAO standard; particulate matter emissions below the ICAO standard; and noise by 25 dB cumulative relative to the FAA Stage 5 standard.

- General Electric Aviation will develop an advanced engine propulsion system and advanced acoustic improvements to reduce noise and fuel consumption; electric and hybrid-electric systems to increase fuel efficiency; and advanced combustion and thermal management systems to reduce emissions and fuel consumption. The company also will support the evaluation of alternative jet fuels that could enable further aircraft performance improvements.
- Honeywell Aerospace will develop a more efficient engine fan, combustion system, compressor, and turbine to reduce noise, emissions, and fuel consumption.
- Pratt & Whitney will develop an ultra-quiet engine fan and an advanced combustion system to reduce noise, emissions, and fuel consumption.
- Boeing will develop technologies to reduce noise from the wings, landing gear, and engine inlets. The company also will support the evaluation of alternative jet fuels that could enable further aircraft performance improvements, and help to develop new algorithms that enable aircraft to fly quieter, more fuel-efficient routes.
- Delta TechOps, GKN Aerospace, MDS Coating, and America's Phenix will work together to develop erosion-resistant fan blade coatings to reduce fuel consumption over the life of an engine.
- Rohr Inc. will develop acoustic technology to reduce the noise from engine exhausts.

The FAA also is pursuing agreements with Rolls-Royce Corporation and Safran Nacelles.

"Like our quest for safer skies, making flying sustainable requires us to constantly look for ways to improve," said FAA Administrator Steve Dickson.

The CLEEN technologies developed so far are estimated to reduce CO2 emissions equivalent to removing 3 million cars from the road by 2050 and to save the aviation industry 36 billion gallons of fuel. The fuel savings is the equivalent of 11.4 million Boeing 737 flights between New York and Los Angeles.

Continuing Success

Examples of the accomplishments from the FAA's $225 million invested in the CLEEN Phase I and Phase II include:

- Enhanced jet engine combustion systems have entered the aviation fleet, resulting in lower emissions.
- Advanced aircraft wings made of stronger and lighter-weight materials are supporting innovative development of current and future aircraft.

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15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

- Flight Management System algorithms have been created under CLEEN to enable aircraft to fly more fuel-efficient routes.
- Several alternative jet fuels have been certified for safe use, due in part to testing and evaluation efforts conducted under CLEEN.

The FAA anticipates that technologies developed under CLEEN Phase III could be introduced into commercial aircraft by 2031.

See the CLEEN Program website for more program information and detailed descriptions of CLEEN technologies and benefits.

The recovery this summer to 70% of 2019 flights conceals wide variations

In August, flights were back to 71% of 2019 levels across Europe. This average, however, conceals a wide variation between countries and also between different traffic flows for each country. The graphic illustrates this variation, taking examples from some of Europe's larger aviation markets.

We noted in a data snapshot in March that domestic flights were holding up better during the pandemic than international flights. This summer, that trend has continued. Turkey, indeed, exceeded 2019 domestic flight counts already in July. Then Italy beat that in August, reaching 107% of 2019, with France, Greece, Norway and Spain all at 90% or more. In the graph, German domestic flights stand out by being overtaken by other flows.

International arrivals and departures include long- and short-haul, and both passenger and cargo flights. COVID-19 passenger travel restrictions have mostly affected international passenger flights and this is reflected in the relatively low figures for international flights (as compared to domestic ones). From the graph, UK and Norway remain particularly weak on this flow: still less than half of 2019 levels. Key holiday destinations, on the other hand, saw a rapid recovery in July and even more in August.

Overflights, not touching an airport in the country, often make a significant contribution to revenues of a country's air navigation service provider. The UK has the weakest overflights of these eight countries, with both Ireland and North Atlantic, which make up most of this flow, slow to recover. Italy and Spain are much stronger, with a strong acceleration starting in July; for example, Italy picked up flights from France and Switzerland to Greece, both of which are already above 2019 counts.

See attached

EASA publishes Flight Data Monitoring of new safety issues arising from the COVID-19 pandemic

The COVID-19 pandemic has posed many new safety issues and changes to safety priorities for operators. These changes may require adapting the scope of the Flight Data Monitoring (FDM) programmes and their way of operating.

This analysis document was presented at a FDM workshop of EASA SAFE360° – 2021 and covers the following topics:

- What has been the impact of the COVID-19 pandemic on the FDM programmes?
- What do the new safety issues brought by the pandemic mean for FDM programmes?
- What is the foreseeable impact of a return to normal operations?

The document was prepared in collaboration with FDM experts from the aviation industry. It contains industry good practice. The document does not have the status of official EASA guidance.

Aeronautical Information Services Manual (Doc 8126) - (Advance) 7th Edition, 2021 –

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Bulletin Officiel des Ministères de la Transition écologique et solidaire et de la Cohésion des territoires et des Relations avec les collectivités territoriales (developpement-durable.gouv.fr)

SIA - La référence en information aéronautique - Page d'accueil (aviation-civile.gouv.fr)

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http://www.developpement-durable.gouv.fr/Objectif-Securite-lebulletin.html

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Cabinet d'Expertise en Aéronautique - Inscrit près la cour d'appel d'Amiens – Indépendant de l'EASA
15, le souguehain – Sénécourt – 60140 BAILLEVAL - tél : +33 (0)6 13 66 05 99 - mail : *philippe.julienne.aeroprojet@live.fr*

UNITED STATES

Aviation Greenhouse Gas Emissions Reduction Plan

U.S. Aviation Greenhouse Gas Emissions
Reduction Plan Submitted to the International
Civil Aviation Organization, June 2012

UNITED STATES
AVIATION GREENHOUSE GAS EMISSIONS REDUCTION PLAN

I. SUMMARY

The United States Government (USG) is committed to addressing the climate change impacts of commercial aviation and is pursuing a multi-pronged approach to achieve greenhouse gas (GHG) emissions reductions. The USG already achieved significant reductions in GHG emissions from, and energy efficiency improvements in, the aviation sector over the past decade through public and private efforts, and it is on a trajectory to continue that progress in coming years. The USG has set an ambitious overarching goal of achieving carbon-neutral growth for U.S. commercial aviation by 2020, using 2005 emissions as a baseline[1]. Given current forecasts for aviation growth this equates to about a 115 million metric tons (MT) reduction in carbon dioxide emissions from commercial aviation by 2020, and by extending those approaches further there could be an additional 60MT reduction by 2026.[2] As part of the Next Generation Air Transportation System Plan, the USG has laid out plans and initiatives for improvements in technology and operations, advances in development and deployment of sustainable alternative fuels, and policies and selective measures to incentivize transition of the fleet and airspace system.

The USG efforts with respect to commercial aviation are supported and enhanced by research efforts of the United States Department of Defense (DoD) to improve energy efficiency in the defense sector.

This plan identifies actions and progress toward GHG emissions reductions in each of the following areas:

- **Aircraft and Engine Technology Improvement** – Within the USG technology research and development efforts there are multiple technology initiatives that are dedicated to developing technology with significantly improved fuel burn and lower GHG emissions. These plans are coordinated through the National Aeronautics Research and Development Plan.[3]

- **Operational Improvements** – The Federal Aviation Administration (FAA) is overhauling the National Airspace System through the NextGen program to improve efficiency and reduce aircraft fuel burn. NextGen is the top aviation priority for the USG, and it has bipartisan support in Congress. Additionally, the Obama Administration has identified a major NextGen project in Houston, Texas for expedited project delivery.

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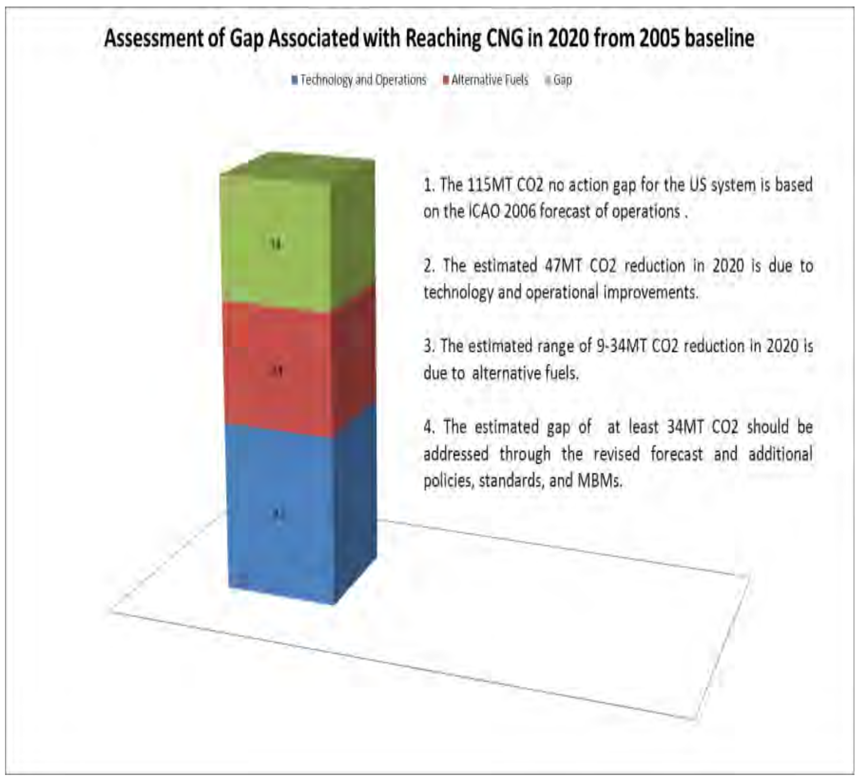
[1] Goal adopted by the Obama Administration and unveiled at COP/15 and subsequently proposed by the U.S., Canada and Mexico at the ICAO Assembly in 2010. The 2005 baseline is calculated using the FAA Aviation Environmental Design Tool.
[2] These estimates include all U.S. flights (foreign and U.S. carriers).
[3] National Aeronautics Research and Development Plan available at http://www.whitehouse.gov/sites/default/files/microsites/ostp/aero-rdplan-2010.pdf

- **Alternative Fuels Development and Deployment** – The USG has taken significant steps during the last five years to facilitate the development and deployment of sustainable alternative aviation fuels. Future efforts are aimed at identifying new alternative fuels pathways as well as commercialization of fuels with up to 80 percent lower lifecycle GHG emissions.

- **Policies, Standards, and Measures** – The USG is pursuing or considering a variety of policies, standards, and measures that will supplement, and in some cases support, efforts on technology, operations and fuels in order to achieve the carbon neutral growth goal.

- **Scientific Understanding and Modeling/Analysis** – The USG conducts ongoing scientific research to better understand and quantify the impacts of aviation on the climate, including consideration of interdependencies and tradeoffs with other environmental impacts. These efforts help identify and prioritize the most effective mitigation options.

Expected Reductions: The USG is undertaking detailed analyses to estimate projected reductions from technology, operations, and alternative fuels in order to assess progress toward the carbon neutral growth goal for U.S. commercial aviation and to identify any gap to be addressed by policies, standards, and measures. This detailed analysis is not ready for submission with the Action Plan, but will be published once completed. Based on preliminary previous work, improvements in aircraft technology and air traffic operations are expected to result in an estimated reduction of 47 MT of CO_2 in 2020.[4] Thus, a substantial portion of the carbon neutral growth 2020 goal is expected to be covered with technology and operational innovation. With respect to alternative fuels, preliminary computations show potential reductions in life cycle CO_2 emissions from alternative fuels between 9 and 34 MT. [5] By assuming the best case for



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[4] This reduction is calculated based on an expected 1.5 percent improvement in fuel efficiency per year due to technology and operational improvements, measured relative to a baseline year of 2010.

[5] This reduction is based on a "bottom up" projection conducted by the Volpe Transportation Center that analyzed responses from 61 companies using 18 fuel production processes to estimate potential of alternative aviation fuel

alternative fuels, to achieve carbon neutral growth in 2020 using a 2005 baseline, would require another 34 MT. These reductions can be achieved from a combination of lower actual emissions growth rates[6] and use of policies, standards, and measures.

II. AIRCRAFT AND ENGINE TECHNOLOGY IMPROVEMENT

The evolution of newer, more fuel-efficient airframes and engines has produced the most significant aviation emissions reductions historically and will drive more reductions in the future. The USG is leading a number of efforts and collaborating with the aviation industry to develop and improve technology that results in better fuel efficiency and reduced emissions. USG actions to improve aircraft and engine technology are carried out by the FAA, the National Aeronautic and Space Administration (NASA) and the Department of Defense (DoD) and coordinated through the National Aeronautics Research and Development Plan[7].

A. PROGRAM SPECIFICS

FAA's Continuous Lower Energy, Emissions and Noise Program

The Continuous Lower Energy, Emissions, and Noise (CLEEN) program, launched by FAA in 2010, is a collaborative partnership with five aviation manufacturers to develop technologies that will reduce emissions and fuel burn, to enable alternative fuel use and to expedite integration of these technologies into current and future aircraft. CLEEN is focused on the complete aircraft and includes improvements in aerodynamic and structural efficiency as well as civil propulsion efficiency. The total federal investment is expected to be $125 million over five to six years with the five aviation manufacturers contributing cost-share that matches or exceeds the federal investment. The CLEEN program focuses on advancing pre-commercial technologies for inclusion in the commercial aircraft fleet beginning in 2015. [8]

The CLEEN program is fully authorized and has received at a minimum full appropriation each year. Given the bipartisan support for this program so far, continued support for this program in the budget is expected.

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production in North America (the United States, Canada, and Mexico) in 2020. The range of values represents potential variation in the amount of alternative fuels these companies produce for the jet fuel, diesel fuel, and gasoline markets.

[6] Note that these preliminary computations are based on an ICAO 2006 forecast of aviation growth that has substantially overestimated U.S. aviation growth. This forecast is being refined and we expect that the new forecast will create a smaller gap.

[7] See National Aeronautics Research and Development Plan *available at* http://www.whitehouse.gov/sites/default/files/microsites/ostp/aero-rdplan-2010.pdf

[8] For additional information on the CLEEN program, please see http://www.faa.gov/about/office_org/headquarters_offices/apl/research/aircraft_technology/cleen/.

NASA's Environmentally Responsible Aviation and Subsonic Fixed Wing Programs

The CLEEN Program is complemented by NASA's efforts via the recently launched Environmentally Responsible Aviation (ERA) Project within the Integrated Systems Research Program (ISRP) for next generation technologies and the Subsonic Fixed Wing (SFW) Project within the Fundamental Aeronautics Program for longer term technology development.[9] Created in 2010, ERA is a six year focused effort performed in collaboration with the FAA and DoD with the aim to reduce mission fuel burn by 50 percent. Similar to CLEEN, ERA is focused on the complete aircraft and includes improvements in aerodynamic and structural efficiency as well as civil propulsion efficiency. In 2011, ERA received $65 million in funding and the project is expected to be funded at over $70 million each year from 2012 through 2015. ERA will accelerate development of these technologies for potential introduction into emerging subsonic passenger and cargo transport aircraft and engine designs no later than 2020.

NASA's enduring Fundamental Aeronautics Program continues to focus and pursue fundamental research into advanced rotary wing, subsonic and supersonic transport aircraft designs and associated enabling technologies. The goal of the SFW project is to decrease fuel burn by 70 percent below today's technology by maturing emerging aircraft and engine designs slated for introduction into the fleet beyond 2030. The SFW project is funded at the level of about $90M to explore and advance the most promising long-term technologies for subsonic transports.

Department of Defense Programs

Beyond efforts by FAA and NASA focused on commercial applications, DoD is investing significant resources in more energy efficient aircraft technology to address escalating fuel cost and supply volatility. DoD and its various branches have a number of specific military propulsion programs and initiatives underway to improve aircraft energy efficiency, which will also reduce GHGs. The VAATE (Versatile Affordable Advanced Turbine Engines) Program provides a framework to develop advanced engine technologies for all DoD services, in collaboration with the Defense Advanced Research Projects Agency (DARPA), Department of Energy (DOE), NASA, FAA and industry. There are several technology development programs under VAATE that strive to meet specific energy goals. The Adaptive Versatile Engine Technology (ADVENT) Program is developing critical technologies to enable military turbofan engines with 25 percent

On September 7, 2010, a U.S. Air Force C-17 flew with all engines burning a JP-8, biofuel, and synthetic coal-derived fuel blend.

[9] For additional information on the ERA project, please see http://www.aeronautics.nasa.gov/isrp/era/index.htm. For additional information on the SFW project, please see http://www.aeronautics.nasa.gov/fap/subfixed.htmlhttp://www.aeronautics.nasa.gov/isrp/era/index.htm

improved fuel efficiency that reduce fuel burn and provide more range, persistence, speed and payload. The Adaptive Engine Technology Development (AETD) program is following the ADVENT program to accelerate technology maturation and reduce risk for transition of these technologies to a military engine in the 2020+ timeframe; the technology would be applicable to a range of military aircraft (fighters, bombers, etc.). In addition, the DoD is investing in advanced aircraft configurations and lightweight structures to improve aircraft efficiency. Many of the technologies being developed under these programs will be transferable to the commercial aviation fleet and vice-versa.

B. TIME FRAME AND TARGETS

The FAA CLEEN, NASA ERA, NASA SFW Program and DoD VAATE Program goals are complementary in their reduction targets and their timeframes.

- A primary goal of the CLEEN program is to develop and demonstrate, by 2015, technology that reduces fuel burn by 33 percent relative to current technology. The technology would then be available for commercialization.

- The Environmentally Responsible Aviation (ERA) project has a goal to reduce mission fuel burn by 50 percent not later than 2020 for subsonic passenger and cargo transport aircraft. In addition, the DoD ADVENT and AETD programs have a goal of a 25 percent improvement in fuel efficiency for military engines by 2020.

- The Subsonic Fixed Wing (SFW) Program intends to mature technology associated with emerging aircraft and engine designs slated for introduction into the fleet beyond 2030 to decrease fuel burn by 70 percent.

C. EXPECTED EMISSIONS IMPACTS

An independent expert panel convened in ICAO, and supported by U.S. experts, estimated that new technologies and changes to aircraft mission specifications, such as reduction in cruise speed, could result in as much as 20-30 percent improvement in fuel efficiency by 2020 (when compared with 2000) and 25-50 percent improvement by 2030. The independent experts noted that greater reductions could be expected beyond 2030.[10]

These technologies are currently being advanced by industry as well as FAA and NASA funded research. The aircraft and engine technologies being developed in the CLEEN program have a goal of a 33 percent reduction in fuel burn, relative to current technology, in the near term. The introduction of the aircraft concepts and technologies currently being developed by NASA in ERA and the SFW Program, which, after maturing further, could be brought closer to commercialization by the CLEEN program, could yield much larger reductions on the order of 50 to 70 percent below current levels.

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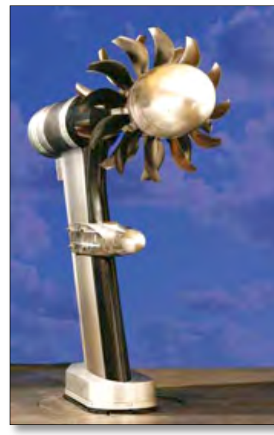
[10] See Report of the Independent Experts of Fuel Burn Reduction Technology Goals, CAEP Steering Group 2010, Working Paper 11 at Paragraph 8.

D. SUCCESSES SO FAR

In partnership with industry, CLEEN is already accelerating development of aircraft technologies that reduce fuel burn. Following were some of the program achievements in FY11:

- Boeing: Completed Adaptive Trailing Edge wind tunnel tests in May 2011, demonstrating improvements in aerodynamic efficiency, leading to an estimated 2 percent reduction in aircraft fuel burn and emissions. Flight tests are scheduled for August 2012.
- GE: Completed sub-scale open rotor wind tunnel tests in January 2012. Early assessments using test data show at least a 26 percent reduction in fuel burn for a single aisle class aircraft. Independent assessments by NASA using test data show a 35 percent reduction in fuel burn is possible.
- Boeing: Completed Alternative Fuel Impact on Aircraft Fuel System tests, demonstrating rubber seals are not adversely affected by a blend of alternative jet fuel and Jet A fuel.
- Rolls-Royce: Completed turbine blade component tests in July 2011, demonstrating a reduction in weight and increase in engine efficiency.


Open rotor model

III. OPERATIONAL IMPROVEMENTS

Achieving more efficient aircraft operations is another critical element for reducing GHG emissions from aviation. The FAA is currently implementing a comprehensive, multiyear overhaul of the National Airspace System known as NextGen. The benefits of NextGen are many and go well beyond environment, but key elements of NextGen include reducing delays, establishing more precise routes, and improving overall efficiency of the National Airspace System, which all result in less fuel burn and lower emissions.

A. PROGRAM SPECIFICS

Implementation of FAA's Next Generation Air Transportation System (NextGen) is a comprehensive means for achieving more efficient aircraft operations and reduced GHG emissions through airspace, operational, and infrastructure improvements (note the CLEEN program referenced above is an element of NextGen). There are a range of operational improvements being implemented that result in lower fuel burn, including use of more precise flight paths with advanced avionics, use of continuous descent arrivals that require limited engine thrust when descending to an airport, and overall airspace optimization.

The USG has dedicated significant resources to implementing NextGen and measuring progress toward NextGen goals, including efforts to measure and quantify environmental benefits. These efforts with detailed information about investments, timelines, etc. are addressed in FAA's NextGen Implementation Plan[11] and NextGen Segment Implementation Plan.[12]

The FAA is working very closely with various segments of the U.S. aviation sector, as NextGen requires not only new infrastructure and systems, but avionics equipage, pilot training, and new ways of operating by the commercial sector. U.S. industry is very supportive of NextGen modernization given the efficiency gains and fuel costs savings enabled.

NextGen has generally received broad congressional support, and even in the recent years of budget challenges, has been funded at or near requested levels. The recent passage of a four-year FAA reauthorization provides further evidence of the widespread support for implementing NextGen, and also provides specific additional authority and support for NextGen programs.

B. TIME FRAME AND TARGETS

Given the broad scope of NextGen, there is a comprehensive planning and implementation process for achieving the full range of NextGen benefits. Implementation of many improvements under NextGen is occurring now with individual elements being implemented throughout the next ten years. The emissions reductions resulting from NextGen are intended to support the overall goal of carbon neutral growth by 2020.

Because of the importance of NextGen to the U.S. economy, President Obama identified one significant NextGen project for fast-tracking as part of the Administration's efforts to speed infrastructure development.[13] The accelerated project involves operational improvements in and around the two largest Houston airports and surrounding airspace. The estimated annual benefits of the project are (1) reducing fuel consumption between 3 and 8.6 million gallons; and (2) reducing GHG emissions by 31,000 to 87,000 metric tons.

C. EXPECTED EMISSIONS IMPACTS

Benefits from NextGen efforts are projected to result in a cumulative reduction of approximately 1.4 billion gallons of fuel or 14 MT of CO_2 by 2020. This is a system-wide estimate and is highly sensitive to FAA's air traffic forecast, which has been highly variable in recent years due to a number of factors, including fluctuation in fuel prices and the economy.

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[11] *Available at* http://www.faa.gov/nextgen/media/ng2011_implementation_plan.pdf

[12] *See also* National Airspace and Procedures Plan for additional details regarding the milestones and products that will support achieving success in NextGen

[13] *See* Presidential Memorandum regarding "Speeding Infrastructure Development through More Efficient and Effective Permitting and Environmental Review" (Aug. 31, 2011) *available at* http://www.whitehouse.gov/the-press-office/2011/08/31/presidential-memorandum-speeding-infrastructure-development-through-more

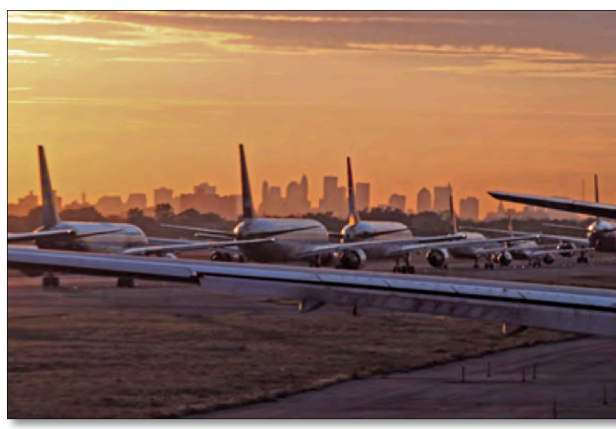
D. SUCCESSES SO FAR

The following are a few of the many NextGen projects and programs that have demonstrated emissions reductions and will lead to greater reductions as they are fully implemented or expanded upon.

- **FAA Metroplex Initiative:** FAA's Metroplex initiative is undertaking efforts to optimize the complex airspace in the vicinity of busy U.S. airports. Under this initiative, implementation of optimized descents and shorter flying distances in Washington, D.C. and north Texas has resulted in a substantial reduction in aircraft fuel burn. For Washington, the estimate is $6.4 to $19 million per year in fuel savings, and the north Texas Metroplex estimated to save $10.3 to $21.7 million. In Houston alone, between 3 and 8.6 million gallons of fuel will be saved, the equivalent of taking 4,000 to 8,000 cars off the road in the metropolitan area. The Washington and north Texas projects moved to the design and implementation phase in 2011.[14]

- **Atlantic Interoperability Initiative to Reduce Emissions (AIRE)**: AIRE is a collaborative effort between the U.S. and the European Commission to promote and harmonize environmental initiatives and procedures in European and North American airspace. In 2010 and 2011, the U.S. participated in three AIRE demonstration projects utilizing a combination of flight optimization procedures to reduce fuel burn and emissions. Benefits ranged from a savings of 100 to 400 gallons of fuel per flight.

- **Reduced Surface Emissions**: During 2010, the Port Authority of New York and New Jersey implemented a surface congestion reduction program at JFK airport to avoid disruption while the airport's longest runway was being rebuilt. Adapting software used during de-icing operations, JFK managers tracked and limited access to taxiways for departing aircraft until they could take off without delays. JFK retained the procedure after the runway work was completed, and analysts were able to compare operations using the system under normal circumstances with operations before the runway work began. Through FAA analysis, it is estimated that the procedure has the potential to save 14,800 hours of taxi-out time per year at JFK, reducing fuel consumption by 5 million gallons and carbon dioxide emissions by 48,000 metric tons.



Surface congestion at Kennedy International Airport.

[14] NextGen Implementation Plan, Page 20.

IV. ALTERNATIVE FUELS DEVELOPMENT AND DEPLOYMENT

The USG is actively supporting and facilitating the development and deployment of sustainable alternative fuels with lower lifecycle GHG emissions than conventional petroleum fuel.

A. PROGRAM SPECIFICS

The USG has taken significant steps during the last five years to facilitate the development and deployment of "drop-in" alternative aviation fuels. "Drop-in" jet fuel can be used without changes to aircraft systems or fueling infrastructure and may reduce aircraft emissions and enhance U.S. energy security. The Commercial Aviation Alternative Fuels Initiative (CAAFI), a public/private partnership between the USG, airlines, aircraft manufacturers and airports, has led efforts in research and development, environmental assessment, fuel testing and demonstration and commercialization of alternative aviation fuels. CAAFI efforts contributed to the creation of testing protocols and new alternative fuel specifications that have enabled approvals for aviation to use new fuels in commercial service. This is paving the way to large scale production and use of these fuels. This leadership has also helped make aviation a major target market for the alternative fuels sector.


US agencies contribute to aviation alternative fuels efforts with R&D, fuel testing, and production investments.

The U.S. Department of Agriculture (USDA) considers aviation a key strategic partner and market for accomplishing its goals of promoting bioenergy production and supporting rural development. The USDA is focused, in particular, on crop and investment programs to support aviation fuel production. Likewise, the Air Force, the Navy, NASA and Department of Energy have also become key government contributors to aviation alternative fuels efforts with research & development, fuel testing and fuel production investments. The U.S. Renewable Fuel Standard (RFS) mandates the use of 36 billion gallons of renewable fuels by 2022 but does not mandate jet fuel production. The U.S. Environmental Protection Agency (EPA) has proposed that alternative aviation fuels get credit toward the volume requirement thereby enhancing the potential commercial value of the qualified fuels and creating further incentive for production.

B. TIME FRAME AND TARGETS

In general, for an alternative jet fuel to be broadly used by commercial aviation, it needs to be approved by ASTM International (ASTM), a widely recognized industry standards setting organization. To date, ASTM has approved two alternative jet fuels that could use vegetable and waste oils as well as lignocellulosic materials with Fischer-Tropsch synthesis. The approval of additional alternative jet fuels is being pursued to ensure that a wide range of feedstock and fuel producers have access to the jet fuel market, reducing cost and thereby providing greater opportunity to meet U.S. environmental goals.

FAA, DoD, and NASA are currently collaborating with industry to advance additional fuel pathways that could more cost effectively convert materials to alternative jet fuels. Once sufficient testing is completed, ASTM is expected to consider approval of the next fuel types, in late 2013 or 2014. In the interim, the FAA is working with the Brazilian government to facilitate the use of alcohol-to-jet fuel on a specific aircraft type in Brazil in time for the World Cup in 2014. This fuel pathway could use a wide range of feedstocks that can be converted to alcohols, which are then upgraded to jet fuel. In parallel, additional fuel pathways are also under development and testing and being considered for approval.

A forthcoming analysis from the Volpe Transportation Center presents a "bottom up" projection of the potential production of alternative aviation fuels in North America (the United States, Canada, and Mexico) in 2020 that is based on 61 companies using 18 fuel production processes.[15] It must be noted that this is a preliminary analysis that was derived using a number of assumptions that are currently being vetted. For North America, alternative aviation fuel production in these specific scenarios was projected to range from 2.5 billion gallons per year (BGY) to more than 9 BGY. The projections reflect individual company stated plans – as opposed to the underlying market forces – for production and expansion. The analysis also projects the role that alternative fuels may play in achieving carbon neutral growth goals under various production scenarios.

The Volpe Center projects alternative aviation fuel production could range from 2.5B to more than to more than 9B gallons per year by 2020.

The FAA has set a goal of annual use by U.S. aviation of 1 billion gallons of alternative jet fuel, by 2018, displacing 1 billion gallons of petroleum jet fuel. The U.S. Air Force (USAF) has a goal of being ready to cost competitively acquire 50 percent of USAF domestic aviation fuel from domestically sourced 50/50 alternative fuel blends by 2016.[16] The U.S. Navy has a goal to have 50 percent of the Naval fleet's total energy consumption from cost competitive alternative sources by 2020.[17] It is a

[15] John A. Volpe National Transportation Systems Center Draft Report entitled "Alternative Aviation Fuel Scenario Analysis Report" Version: 9/23/11.
[16] "Air Force energy plan: 2010," The United States Air Force, 2010.
[17] "A Navy energy vision for the 21st century," The United States Navy, 2010.

legal requirement that alternative fuels be produced in a manner that has a lower greenhouse gas footprint than conventional petroleum based fuels.[18]

C. EXPECTED EMISSIONS IMPACTS

The fuel production pathways examined in the preliminary Volpe "bottoms up" projection had an estimated average 1/3 reduction in life cycle CO_2 emissions.[19] With this life cycle CO_2 value, and the preliminary range of fuel production values from 2.5 to 9 BGY, the overall annual reduction in life cycle CO_2 emissions could be between 9 and 34 MT of life cycle CO_2 emissions by 2020 relative to traditional petroleum fuels.

Alternative fuel analyses conducted by the PARTNER Center of Excellence have shown reductions of up to 80 percent for some renewable alternative jet fuel pathways with many HEFA pathways showing approximately a 50 percent reduction.[20] With an optimistic life cycle CO_2 emissions reduction of 80 percent, the range of fuel volumes presented above could correspond to annual reductions of 23 to 82 MT of life cycle CO_2 emissions by 2020 relative to traditional petroleum fuels.

D. SUCCESSES SO FAR

The following are several examples of the progress and successes in the development of sustainable alternative fuels for aviation.

- On July 1, 2011, the standard-setting organization ASTM International approved a bio-derived sustainable alternative jet fuel known as Hydroprocessed Esters and Fatty Acids, or HEFA, for commercial use up to a 50 percent blend level. This approval required extensive collaboration with all stakeholders over a period of three years with the FAA's CLEEN Program supporting key testing that enabled the approval. In late 2011, two U.S. commercial airlines, United Airlines and Alaska Airlines, flew their first domestic flights powered by HEFA biofuels.

Alaska Airlines flew its first biofueled domestic flight in 2011.

[18] Energy Independence and Security Act of 2007," Section 526, One Hundred Tenth Congress of the United States of America, 2007
[19] John A. Volpe National Transportation Systems Center Draft Report entitled "Alternative Aviation Fuel Scenario Analysis Report" Version: 9/23/11.
[20] Stratton RW, Wong HM, Hileman JI (2010) Life Cycle Greenhouse Gas Emissions from Alternative Jet Fuel, Version 1.2. Cambridge, Massachusetts: PARTNER/MIT.

- USDA provided a $40 million research grant to a University of Washington lead team to focus on using sustainably grown woody energy crops for transportation fuels. The project aims to develop a regional source of renewable aviation fuel. Production of bio-based jet and diesel fuel by project partner Zeachem is expected to begin as early as 2013.

- USDA has invested in a New Mexico facility to produce "green crude" oil from algae, which can be refined into transportation fuel. And USDA and DOE have invested in another algae production facility in Arizona.

- In August 2011, USDA, Department of Energy and U.S. Navy announced a partnership to invest up to $510 million during the next three years to produce advanced, drop-in aviation and marine biofuels to power military and commercial transportation. DOE and DoD plan to invest money under the Defense Production Act Title III, which allows the U.S. to invest in strategically significant industries. USDA plans to provide its contribution through the use of its Commodity Credit Corporation.

- In December 2011, the Navy announced that the Defense Logistics Agency had signed a contract to purchase 450,000 gallons of advanced drop-in biofuel, the single largest purchase of biofuel in government history, for a demonstration off the coast of Hawaii in the summer of 2012.

- The U.S. Department of Energy's ongoing Integrated Biorefineries Program supports development of pilot and demonstration scale fuel production facilities with 11 projects focused on hydrocarbon fuels including jet fuel. DOE is planning additional funding of alternative jet fuel development.

- In April 2012, the Air Force completed testing and certification of the entire fleet on Fischer-Tropsch synthetic fuel and continues to certify the fleet on hydro-processed renewable jet (HRJ) and alcohol-to-jet (ATJ biofuel blends).

- In October 2010, the FAA and USDA signed a five-year agreement that creates a framework of cooperation to leverage expertise of the two agencies to develop alternative jet fuel production. Under the partnership, the agencies bring together their experience in research, policy analysis and air transportation to assess the availability of different kinds of feedstocks that will be needed by biorefineries to produce renewable jet fuels. A recent concrete outcome is the development of a feedstock readiness measurement tool to inform aviation fuel users about availability and feasibility of the key raw materials for alternative fuel production.

- In July 2010, the USDA joined with CAAFI co-sponsor Airlines for America (A4A) and the Boeing Company in a "Farm to Fly" resolution to "accelerate the availability of sustainable aviation biofuels in the United States, increase domestic energy security, and establish regional supply chains and support rural development."

V. POLICIES, STANDARDS, AND MEASURES

The USG is pursuing the development of a meaningful CO_2 standard and considering additional policies, standards, and measures that would supplement efforts on technology, operations and alternative fuels in order to achieve the carbon neutral growth goal.

1. Development of a Meaningful Aircraft CO_2 Standard

The USG is committed to the development of a meaningful CO_2 standard in ICAO for implementation in the U.S. under the Clean Air Act. In this regard, the ICAO Committee on Aviation Environmental Protection (ICAO/CAEP) is currently working toward adopting a meaningful CO_2 standard for aircraft with support from the USG and industry and environmental stakeholders. The CO_2 standard would incentivize faster development of technology and serve as a basis for ensuring that less efficient aircraft and engine technologies are eliminated over time[21].

2. Aviation Fuel Charge

The USG currently applies a domestic per gallon fuel charge of 4.3 cents that contributes to funding $1B yearly NextGen infrastructure development investment and emissions reduction through the Airport and Airway Trust Fund.

3. Incentives for Equipping Aircraft with Advanced Avionics

The recently passed FAA reauthorization grants authority to FAA for the establishment of an incentive program to facilitate the purchase of advanced avionics for aircraft in order to facilitate the implementation of NextGen. The incentive program is in the early stages of design given the recent passage of reauthorization, and the potential for environmental improvement is a critical factor in the design of the program. In addition, by hastening the implementation of NextGen, the incentive program will help lead to overall emissions reductions from aviation.

Advanced avionics facilitate NextGen implementation.

4. Voluntary Airport Low Emissions Program

FAA's Voluntary Airport Low Emission Program (VALE) is a national program designed to reduce all sources of airport ground emissions. Airports can apply for funding to purchase lower emissions technology. Examples of previously funded projects include: preconditioned air units, electric ground support equipment like bag tugs and belt loaders; natural gas refueling stations for airport buses and shuttles; gate electrification; and alternative fuel systems including geothermal systems and solar facilities. In fiscal year 2011, the FAA issued VALE grants for 12 projects at 11 airports for low-emission projects. Since 2005, the FAA has funded 52 low-emission projects at 30 airports

[21] The efficacy of the standard will depend on both the stringency (over time) and applicability of the standard (i.e., to what types of aircraft is the standard applied such as applying to current in-production), both of which are under discussion in ICAO. ICAO/CAEP is aiming to complete work on the standard by 2013.

representing a total investment of $138 million ($109 million in federal grants and $29 million in local airport matching funds) in clean airport technology.

5. NextGen Environmental Management System

FAA has developed and is improving upon a NextGen Environmental Management System (EMS). The EMS will assist in measuring progress toward NextGen Environmental goals and obtain input and commitments from stakeholders on initiatives to reduce fuel burn and emissions from aviation. With the use of analytical models, and information from stakeholders, FAA can provide transparency and information regarding progress toward goals.

6. Market-Based Measures

The USG is considering the possibility of market-based measures (MBMs) for aviation to meet any gap in achieving aviation emission reduction goals. In this regard, the USG is supporting efforts in ICAO to develop a framework for MBMs and to explore the feasibility of a global MBM scheme, consistent with Assembly Resolution A37-19.

A. SCIENTIFIC UNDERSTANDING AND MODELING/ANALYSIS

The USG conducts research to better understand the environmental impacts of aircraft, including climate impacts. This research includes identification of the interdependencies among various emissions and noise, and the extent to which there are tradeoffs in mitigation. The analytical methods and models that we use to assess the environmental impacts are regularly enhanced and improved. Our analytical models are used to provide annual fuel burn and emissions inventories as well as to create future projections of fuel burn and emissions, offering a great deal of transparency. The current and future states are then compared against future goals to identify gaps; thus, allowing us to do a better job at identifying and prioritizing the mitigation solutions that should be pursued. As aircraft technology evolves and operational patterns change we plan to use our improved knowledge base to refine our mitigation solutions to achieve maximum benefit and avoid or minimize negative and unintended consequences.

VI. CONCLUSION

The United States is committed to addressing the climate change impacts of commercial aviation through an integrated strategy of technology, operations, and policy innovation. Our NextGen plan seeks to transform how commercial aircraft operate in our airspace system, the kind of technology used in these aircraft, and the fuels that power them to achieve an ambitious goal of carbon neutral growth for U.S. commercial aviation by 2020, using 2005 emissions as a baseline. It involves a number of public-private partnerships and alignment of economic and environmental incentives that offers a way forward for improvements in system performance that achieves safer, more efficient, and sustainable aviation. Given past ICAO forecasts for aviation growth, the carbon neutral growth goal equates to about a 115 MT reduction in carbon dioxide emissions from commercial aviation by 2020. Preliminary estimates indicate technology improvements, operational changes, and alternative fuels in NextGen offer a plan that could produce about 81 MT in carbon dioxide emissions reductions. The remainder would need to be addressed by other measures or, as we expect, we will have a smaller gap to address as aviation emissions growth will be substantially slower than forecast by ICAO in 2006.

The Boeing Company
Engineering Test and Technology
Boeing Research and Technology

Continuous Lower Energy, Emissions, and Noise (CLEEN II) Structurally Efficient Wing (SEW) Final Public Report

FAA/Boeing CLEEN II
Technology Demonstration Program

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Prepared for:

Levent Ileri
CLEEN II Program Manager
Federal Aviation Administration
800 Independence Ave, S.W.
Washington, DC 20591

Contracts Admin: Adam Iwanow

Prepared by:
Craig Wilsey (PM)
Tim Tyahla (SEW)
Marcus Hart (SEW)
Matthew Giesler

The Boeing Company
PO Box 516, M/C S102-2067, Saint Louis, MO 63166

Table of Contents

List of Figures

CLEEN II SEW
Final Public Report

Overview

Boeing developed, built, and tested a next-generation wing structure that demonstrated significant improvements in structural efficiency. The demonstration showed a continuous weight reduction as compared to the 777-200 baseline. SEW technologies could potentially reduce fuel consumption up to 3.5% through weight reduction of the wing. SEW technologies contribute to the FAA's CLEEN II goal of reducing fuel burn.

The SEW Geometry corresponding to the Wing Component Test Article (WCTA) is shown in Figure 1.

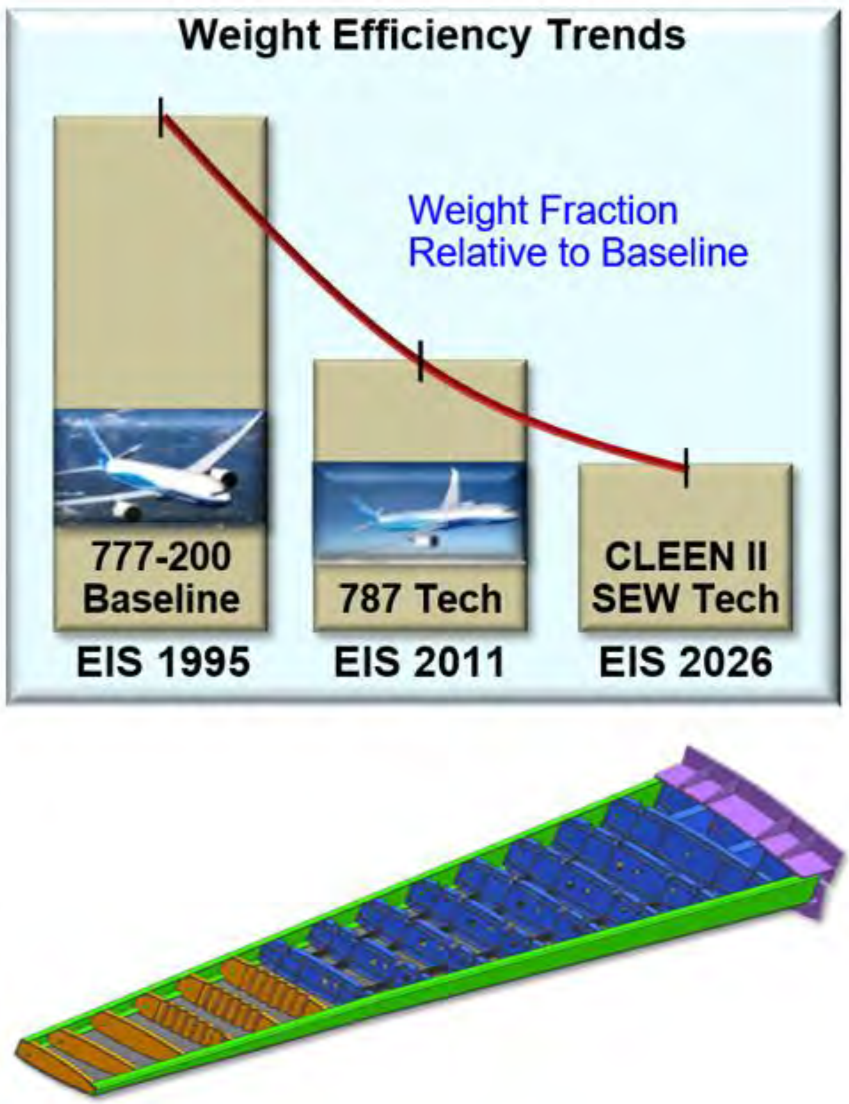


Figure 1 CLEEN II Structurally Efficient Wing (SEW)

The objective of the SEW Program was to demonstrate, through a disciplined building block test approach, a suite of material and structural technologies that contribute to the CLEEN II goal of achieving fuel burn reductions by 2026. Cumulative anticipated benefits projected over twenty years are, Jet A fuel consumption savings of approximately 200 million tons and CO_2 production avoidance of approximately 660 million tons. The technologies, demonstrated in the WCTA, are summarize in Figure 2.

SEW CLEEN II Technology	Goal Impact	Benefits and Application
• Advancing manufacturing technologies • Advanced prepreg composites • Resin-infused stitched blade stringers • Resin-infused hat stringers • Advanced alloy metallic ribs • Resin-infused sine wave rib • Stamped thermoplastic ribs	Fuel burn reduction CO_2 Production Avoidance	Lower weight, higher performance wing

All technologies contribute to the fuel consumption reduction goal by reducing structural weight and/or Drag

Figure 2 CLEEN II SEW Technologies

Technology Development

The major achievements for the SEW Program are summarized in Figure 3. The achievements track the graduation of SEW technologies from Technology Readiness Level (TRL) 3 to TRL 6.

- *Concept of Design Review (CoDR) Completed Early*
- *Preliminary Design Review (PDR) & Coupon Tests Completed (TRL4)*
- *Building Block Tests Completed (TRL5)*
- *Detail Design Review (DDR) Completed Early*
- *Tooling, Part & Test Fixture Fab Completed*
- *Test Readiness Review (TRR) Completed Early*
- *Full Scale Test Series Completed (TRL 6)*

Figure 3 SEW Major Achievements

The specific technologies included in the WCTA are described in Figure 4. The technologies were selected due to their potential for contributing to the FAA's CLEEN II goal of reducing fuel burn through weight reduction of the wing.

The upper skin was made from BMS8-276 composite material. Non-traditional laminates (NTLs) were incorporated to enable aeroelastic tailoring. Upper skin stringers were resin infused and precured prior to co-bonding to the upper skin. The vent stringer was fabricated from braided carbon fiber. The blade stringers were stitched and fabricated from non-crimp fabric.

The lower skin was made from IM+ composite material with higher stiffness compared to BMS8-276. NTLs were also incorporated into the lower skin. Lower skin stringers were also made with IM+ composite material and they were cocured with the lower skin.

The spars were also made from IM+ composite material. The aft spar included a co-cured splice with a kick in the span wise direction to capture realistic complexity representative of typical production designs.

Ribs in the inboard portion of the WCTA were made from Aluminum Lithium (Al-Li). That portion of the WCTA was designated as a wet fuel bay with requirements to sustain internal pressure loads. The pressure loads induce bending in rib flanges fastened to the skins. Laminated composite ribs would include an inherent interlaminar tension (ILT) weakness with increased weight. Therefore, metallic ribs, without the ILT weakness, were chosen.

Ribs in the outboard portion of the WCTA were made from composite material. That portion of the WCTA was designated as a dry bay without requirements to sustain internal pressure loads. Several of the outboard ribs were stamp formed thermoplastic composite ribs. One of the outboard ribs was made of resin infused braided carbon fiber, similar to the vent stringer.

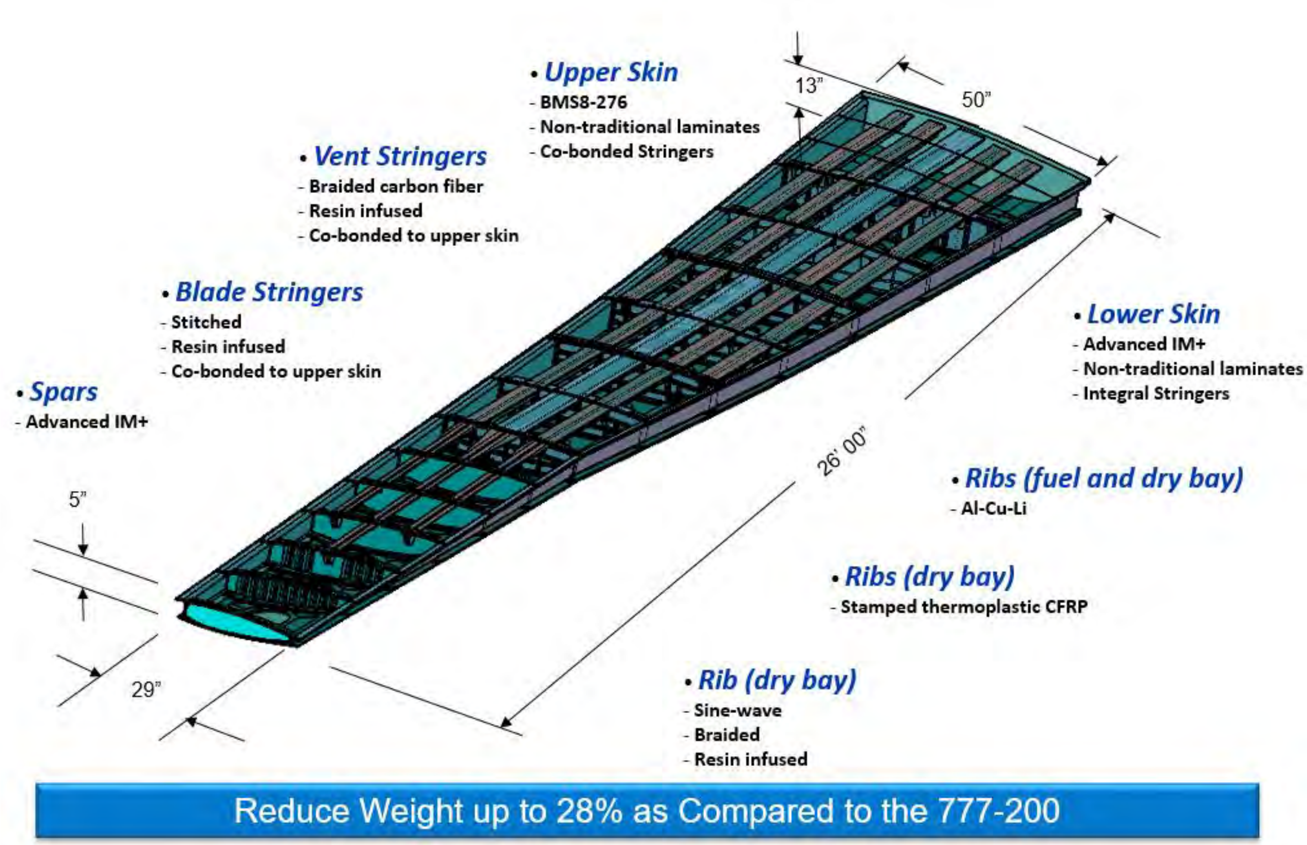


Figure 4 CLEEN II SEW Technology Demonstrations

The SEW Program Schedule is illustrated in Figure 5. It was accelerated to graduate technologies to TRL 6, including building block testing, a full scale static test, and a full scale residual strength test, in order to promote technology transition to future Boeing products. At the end of the program opportunities for additional large notch panel testing and NTL data correlation were leveraged to provide risk reduction in support of far term technology transition.

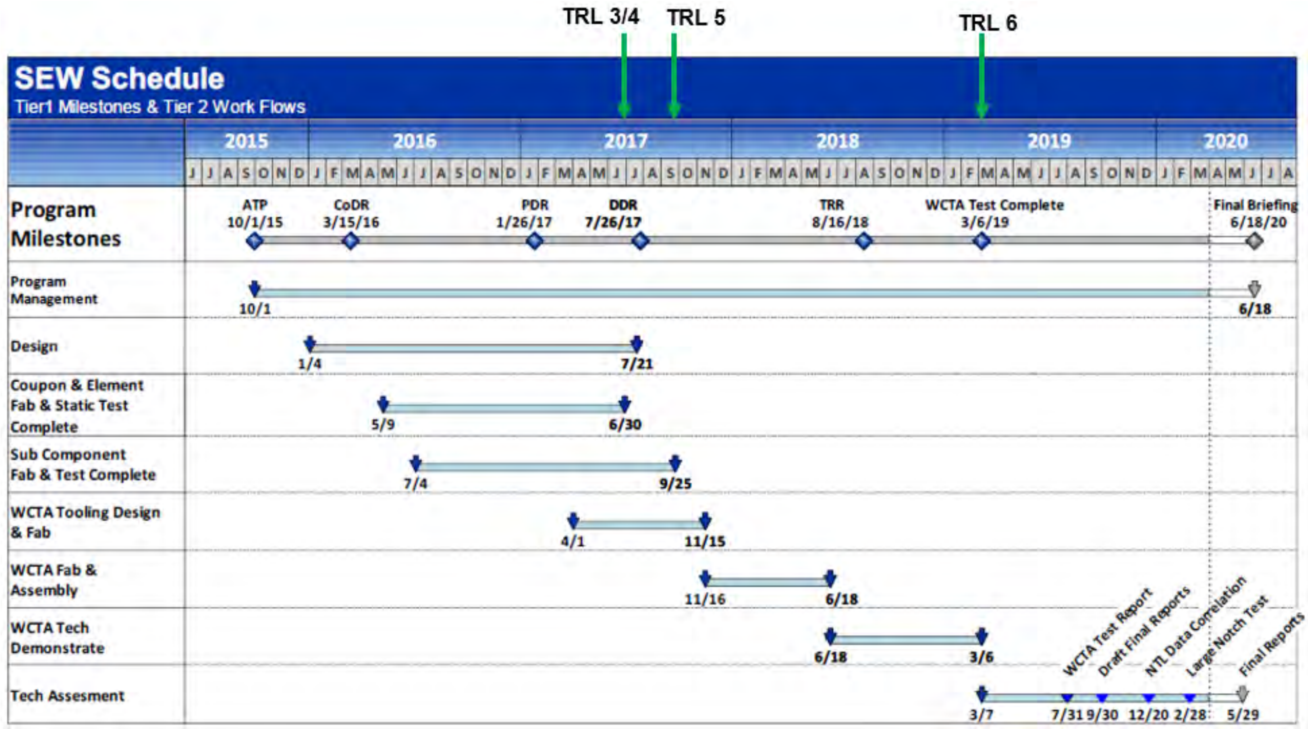


Figure 5 CLEEN II Boeing SEW – Accelerated Schedule

Early assembly preparation is illustrated in Figure 6. The assembly cell included a transport cart to control the position of the lower wing skin during assembly. Tooling was also located around the transport cart to control the position of the spars and ribs. Figure 6 also shows several of the components to be assembled. Those components are the upper skin with co-bonded blade and hat stringers, a resin infused sine-wave rib, and a thermoplastic rib.

Figure 6 SEW WCTA Assembly Preparation

The full scale test of the WCTA was executed by the National Institute for Aviation Research (NIAR) at Wichita State University. The load introduction hardware included fore and aft framework around the WCTA as shown in Figure 7. Load was introduced through load pads at internal rib stations.

Figure 7 SEW WCTA Test

The WCTA was tested successfully to 177% Design Limit Load (DLL) at NIAR. Completion of this test established a TRL of 6 for SEW technologies, including composite material technologies at elevated temperature / wet conditions. Figure 8 shows the WCTA deflected state at 177% DLL.

Figure 8 SEW WCTA Test to 177% Design Limit Load

A residual strength test was performed after the test to 177% DLL to satisfy damage tolerance requirements. Damage was introduced into the WCTA as shown in Figure 9. The damage resided in the upper skin and front spar.

Figure 9 WCTA Residual Strength Test Configuration

The WCTA residual strength test was successfully completed. The area of the WCTA damaged prior to test was painted white for enhanced visualization. Figure 10 shows the overall deformation of the WCTA at failure as well as a close up of the damage in the upper wing skin.

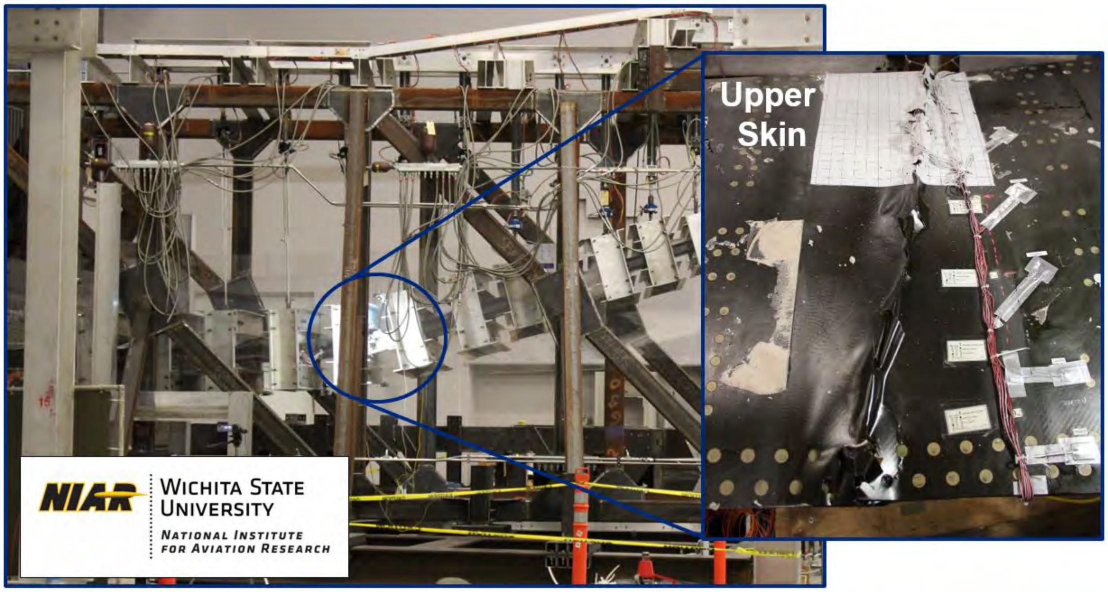


Figure 10 SEW WCTA Residual Strength Test

The WCTA residual strength test results indicated excellent correlation of test data and analysis. Figure 11 shows crack growth versus load data. Video and strain gage test data are shown as blue and orange respectively. Finite Element Model (FEM) analysis data are shown as green.

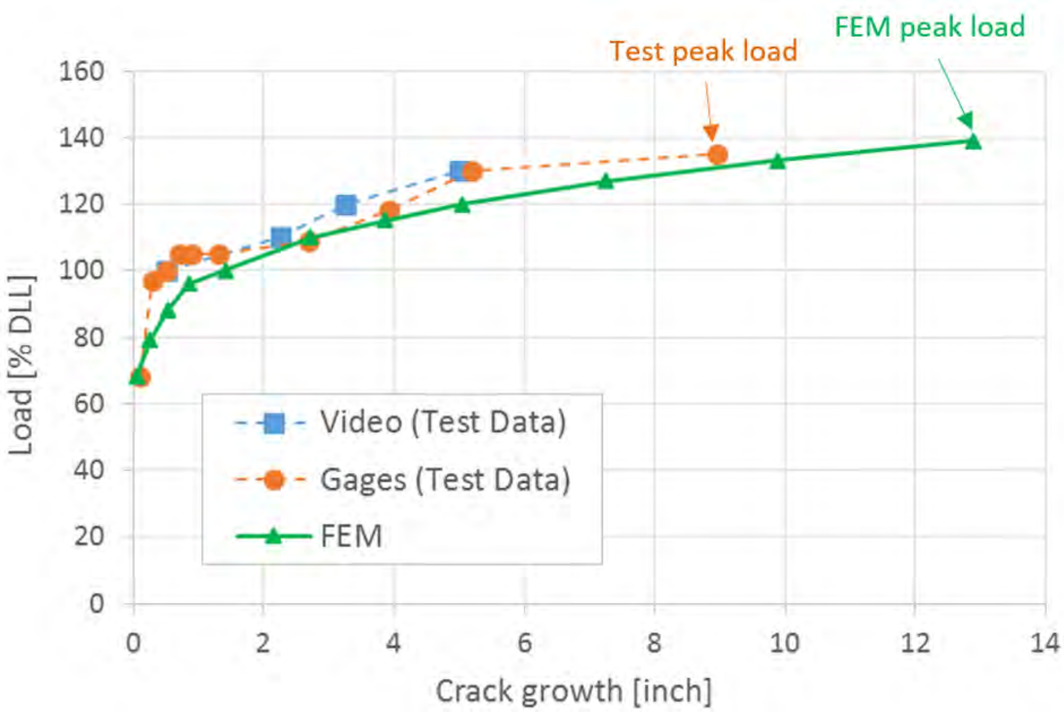


Figure 11 Residual Strength Test Analysis

The WCTA residual strength FEM behavior exhibited excellent correlation with test article behavior as illustrated in Figure 12. Damage propagation shown as red pixels in the FEM correlated well with actual damage observed in the upper skin and front spar.

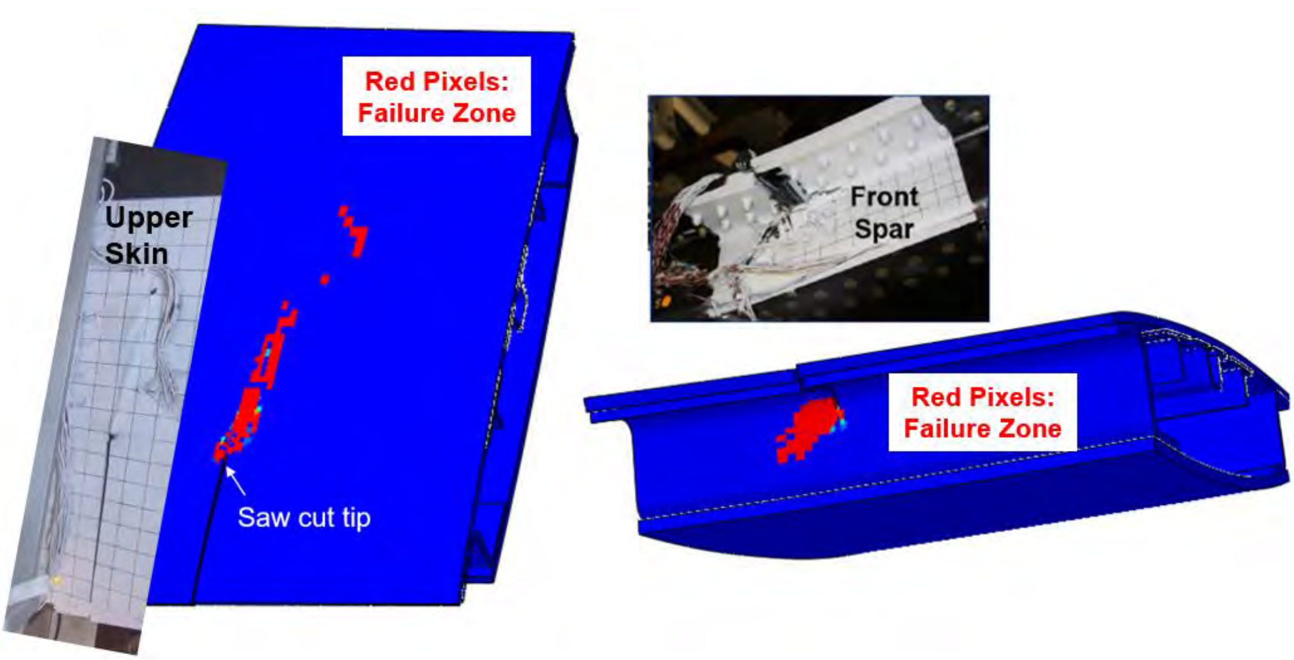


Figure 12 Residual Strength Model Behavior

Summary

The SEW WCTA demonstrated technologies encompassing more efficient materials, laminate definition, and wing box structural configuration. The building block test results support the transition of SEW technologies to commercial transport and military applications. Highlights from the SEW Program include:

- The building-block test approach on SEW developed the selected technologies along the TRL scale, resulting in a TRL 6 demonstration with the completion of the Wing Component Test Article (WCTA) full scale test series.
- SEW contributes to the FAA's CLEEN II goal of reducing fuel burn.
- SEW technologies could potentially reduce fuel consumption up to 3.5% through weight reduction on future commercial transport wing.
- FAA & Industry benefit from continued CLEEN program investment and collaboration.
- The SEW building block development program, which culminated in the WCTA test activity, collectively demonstrated feasibility of numerous structural technologies, some of which could be considered for future commercial airplane development programs.

Acronyms

ATP	Authority to Proceed
CoDR	Concept Design Review
DDR	Detailed Design Review
DLL	Design Limit Load
FEM	Finite Element Model
NIAR	National Institute for Aviation Research
PDR	Preliminary Design Review
SEW	Structurally Efficient Wing
TRL	Technology Readiness Level
TRR	Test Readiness Review
WCTA	Wing Component Test Article

15 December 2020

CONTINUOUS LOWER ENERGY, EMISSIONS, AND NOISE (CLEEN) PROGRAM

Integrated Propulsion System for Commercial Aircraft Technology Demonstrator

Prepared for
FAA Office of Environment and Energy

Prepared under
Contract No. DTFAWA-15-A-80015

Prepared by
Jose Alonso, Chae Huang, Bryce Kelford, Steven Kestler, and Marc Quesada
Collins Aerospace - Aerostructures
850 Lagood Drive
Chula Vista, CA 91910 USA

Table of Contents

EXECUTIVE SUMMARY

Collins Aerospace has developed advanced nacelle acoustic technologies with an intent to implement on the CLEEN II Ground Test (GT) demonstrator unit. The goal of the CLEEN II nacelle has been to enable continued fuel burn performance while improving noise reduction that supports next generation environmental metrics. The CLEEN II Ground Test demonstrator development has been focused on improved drag via introduction of Low Drag Liner and liner configurations including a Fan Duct Novel Liner, and Acoustic Zoned Liner technologies. The initially planned ground test is to enable these technologies to attain TRL 6. Unfortunately, due to unfavorable market and economic scenarios given by the COVID-19 pandemic, the acoustic ground test demonstration has been placed on hold and planned for a mid-term future outside CLEEN. Therefore, the demonstration of benefits in this final report will be solely based on system level acoustic and aerodynamic predictions. These results will serve as the most current measure of the technology performance and benefits, until a ground test validation is performed in the future. The test plan for this future effort has been completed and archived for future use.

Even though it was not possible to execute the ground test, the CLEEN II effort generated multiple outcomes. Selected technologies from the program, e.g. low drag surfaces and zoned liner configurations, have successfully reached production ready status and have been incorporated into current production nacelle applications. In addition, the program helped generate sub-element laboratory test data and advanced prediction tools that allowed quantifying and demonstrating the proposed benefits analytically. The developed acoustic optimization tools have also been incorporated into Aerostructures standard processes for liner optimization. Based on the analytical assessment, it was concluded that the overall EPNL benefit as well as the individual contributions of the liners are in line with the targets and meet the CLEEN II noise improvement goal of 2.0 EPNdB. The predicted total fuel burn benefits of the combined clean fan duct and low drag liner was 0.46%, also in line with expectations.

Finally, the manufacturing maturity of both inlet and fan duct acoustic technologies was significantly advanced by the efforts facilitated by the CLEEN II program and documented in this report.

1. INTRODUCTION

This report documents the efforts conducted by Collins Aerospace to develop advanced nacelle acoustic liners under the Phase II of the Continuous Lower Energy, Emissions and Noise (CLEEN) Program. The CLEEN program is current FAA's principal environmental effort to accelerate the development of new aircraft and engine technologies and advance sustainable alternative jet fuels. The presented efforts support the FAA’s Next Generation Air Transportation System airframe level goals:

1. 40% reduction in fuel burn
2. 75% reduction in nitrogen oxide (NOx) emissions
3. 32 EPNdB cumulative noise reduction relative to Stage 4 standards

The Collins Aerospace contribution to CLEEN II is the development of technologies in support of aerodynamically and acoustically optimized nacelle architectures, enabling lower emissions, energy and noise, aimed at maximizing efficiency of the next generation high bypass ratio propulsion systems for reducing climate impact from aviation. The overall effort includes the development of advanced liner configurations for both the inlet and fan duct components. The acoustic liners were designed and optimized by the acoustics R&T group at Aerostructures, in collaboration with the Raytheon Technologies Research Center (RTRC) that developed the optimization software.

1.1. BACKGROUND

In order to contribute to the CLEEN II goals, the development of Ultra high-bypass (UHB) turbo fan engines is vital to achieve maximum efficiency and noise reduction. UHB architecture features a larger, more slowly rotating fan for a given thrust as compared to legacy designs. Larger fan diameters drive larger nacelle and pylon structures. Given the trend in P&W GTF next generation engines to increase fan diameters to favor efficiency, improvements in Thrust Specific Fuel Consumption (TSFC) and community noise reduction become critical (see Figure 1-1), especially as thrust levels and aircraft takeoff weights increase.

However, as fan diameters increase for a given thrust and fan pressure ratios are reduced to realize TSFC improvements, nacelle weight and drag can increase. This underscores the need to develop technologies that reduce drag and weight for power plant installations that feature UHB engines. One approach to improve performance is to use a shorter nacelle that minimizes the weight impact. The Aerostructures vision to achieve the shorter nacelle, with thrust reverser capabilities, is to incorporate an integrated approach to all the major elements of a propulsion system, such as the engine, nacelle, pylon, and systems. Nevertheless, the shorter nacelle ducts can reduce acoustically treated area, driving the need for more effective acoustic treatment.

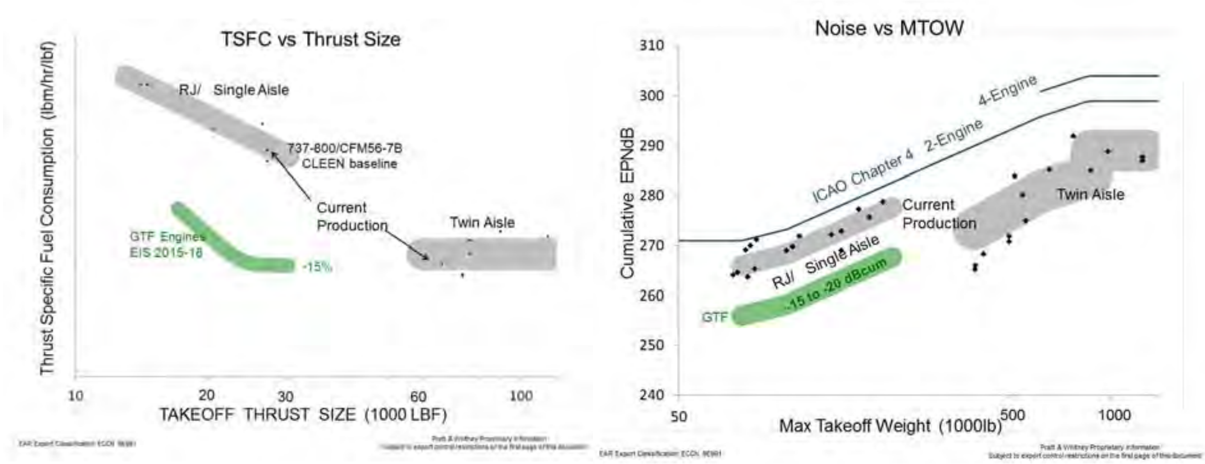


Figure 1-1 Improvements in TSFC and Noise Reduction are Critical on Next Generation Engines

With corresponding improvements in airframe design, this integrated propulsion system (IPS) envisioned by Aerostructures can achieve CLEEN II objectives in the timeframe consistent with an entry into service prior to 2026. The projected benefits of the integrated propulsion system are:

- Fuel Burn Improvement – An additional 1% fuel burn reduction from the reduction in nacelle length and implementation of low drag acoustic surface
- Overall noise benefit of -2.0 EPNdB from implementation of maximum acoustically treated area combined with effective acoustic treatments and segmented liner configurations. This benefit can be utilized to offset the reduction in acoustically treated area that results from a relatively short Inlet and Thrust Reverser ducts.

1.2. ACOUSTIC & LOW DRAG TECHNOLOGIES

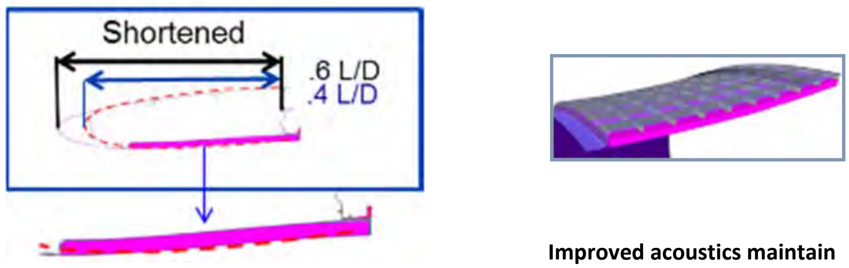
The advanced nacelle acoustic technologies developed under CLEEN II are listed in Table 1-1, including the current Technology Readiness Level (TRL) achieved during the program and the description of the intended benefits.

Table 1-1 CLEEN II Collins Aerospace Acoustic Technologies

Technology	Achieved TRL	Benefits
Zoned Acoustic Liner	6	Tailors acoustic treatment to local tones & aerodynamics plus area maximize
Clean Duct	6+	Increased Acoustic Area, including *Exterior Liner*
Fan Duct Novel Liner	5	Improves acoustic attenuation per sq. ft.
Low Drag Liner	6	Reduces drag in acoustic areas
Short Inlet	3	Improved acoustics or reduced drag

1.2.1. Short Inlet

The proposed short inlet configuration consists on a reduction in the overall length of the inlet from L/D 0.6 to 0.4, seeking less external drag (due to the smaller contact surface) and reduced weight, which both have a direct benefit on fuel burn efficiency. Figure 1-2 shows a schematic of the proposed inlet length reduction. However, this reduction in length has a negative impact on community noise as it yields a significant reduction in the acoustic area necessary to control broadband and tonal noise generated at the fan. As an enabling technology, the proposed effort also includes the development of novel liner concepts that provide improved response relative to current double degree of freedom (DDOF) liners in order to offset for the area reduction. These configurations have also been identified to potentially reduce production cost relative to DDOF liners.



Structural DDOF

Improved acoustics maintain Legacy noise levels

Figure 1-2 Short Inlet Configuration incorporating Advanced Acoustic Liners

1.2.2. Advanced Fan Duct

The Advanced Fan Duct system includes the Clean Duct Acoustic Liner, the Zoned Liner, a novel Fan Duct Liner, and Low Drag Liners. The Clean Duct simulates the acoustic area that would be achieved by a future advanced reverse thrust mechanism that improves fan duct aerodynamic performance (reduces fan duct pressure losses) and increases acoustically treated area for a given fan duct length. To reduce these losses and improve fan duct performance, the envisioned Integrated Thrust Reverser architecture removes blocker door deployment mechanisms (drag links) from the fan stream, where they currently reside on legacy applications, as shown in Figure 1-3. The increased acoustic area configuration also includes treatment on the fan duct inner wall surface located on the aft section outside the fan duct exit plane and thus, external to the fan duct.

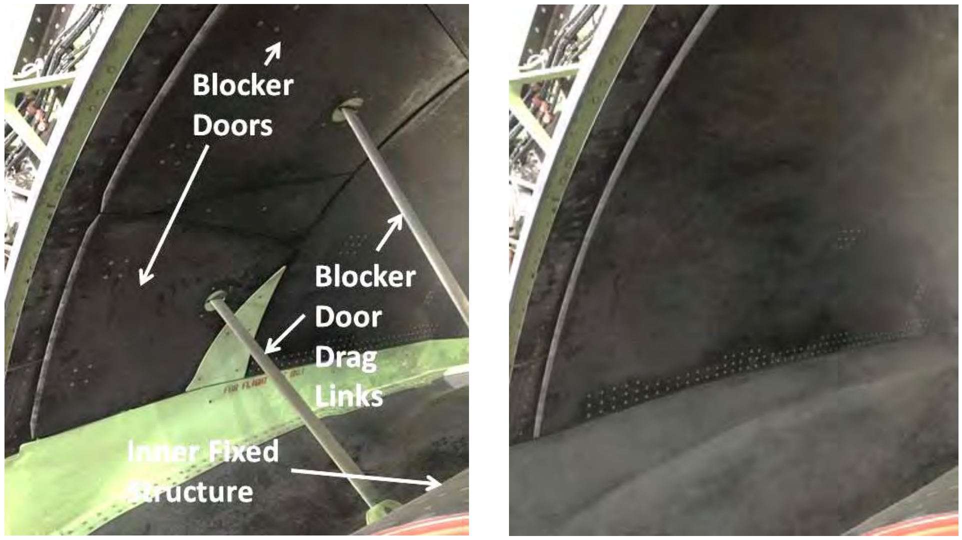


Figure 1-3 Legacy Thrust Reverser Fan Duct (left) Compared to a future Integrated Thrust Reverser

Zoned acoustic treatment offers the potential to tune the attenuation of the treatment down the length of the fan duct. This is achieved by varying the honeycomb core height and skin perforation configuration in the bond panel, allowing, for instance, deeper core to attenuate the prevalent lower noise tones at one location in the fan duct while allowing for reduced height honeycomb core thickness in another part of the fan duct to attenuate the higher noise tones that might be found in that area.

A novel acoustic liner, targeting reduced panel depth, with the potential for equal or better acoustic performance relative to legacy honeycomb is another acoustic technology that is incorporated in the advanced liner configuration. This technology can allow for fewer constraints on designing an optimum fan duct aerodynamic shape as compared to the constraints that legacy honeycomb core heights exhibit. When combined with zoned acoustic treatment, a synergy is created that results in a potential for reduced overall panel thicknesses and more optimal fan duct shapes while increasing broad-band noise attenuation performance. The zoned liner and novel liner are illustrated in Figure 1-4.

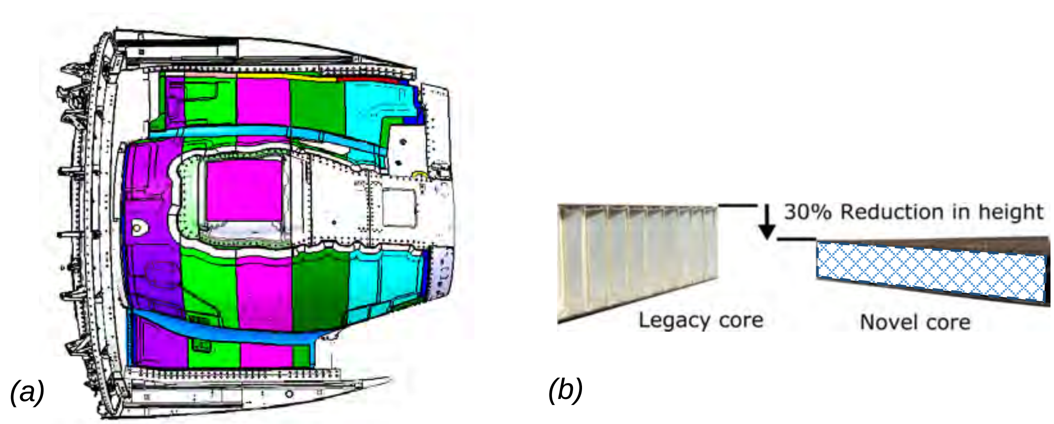


Figure 1-4 (a) Zoned Liner and (b) Novel Acoustics Technologies

The Low Drag Liner technology consists in small hole perforations leading to reduced skin friction and pressure drag in the presence of grazing flow while providing the same acoustic performance as current state-of-the-art liners.

1.3. PROGRAM GOALS

The main objectives of the development program are to mature and demonstrate the performance of the liner technologies listed in Table 1-2. The targeted overall noise benefits of the new nacelle system are 2.5 EPNdB with a legacy (long) inlet and 2.0 EPNdB if the inlet is reduced in length. Therefore, the advanced inlet acoustic liners are primarily intended to offset acoustic area losses due to the shortened length. The overall fuel burn benefits are 0.55% with a legacy inlet, and 1.05% with the short inlet configuration.

For demonstration of these goals, the original plan consisted on reaching acoustic TRL 6 on all fan duct technologies through ground test demonstration using a PW1500G GTF engine at the Pratt & Whitney's C-11 test facility in West Palm Beach, Florida, and acoustic TRL 5 on the short inlet technologies. However, due to evolving market conditions and the recent COVID-19 pandemic, the ground testing has been placed on hold and will be resumed in the future outside of CLEEN II. The test plan for this effort has been completed and archived for future use. In addition, all further tests supporting short inlet technologies have also been placed on hold to be continued as future work. As a consequence, the technology demonstrations will be carried out by analysis.

Table 1-2 Acoustic Technologies Demonstration Goals

Technology	Fuel Burn (%) Improvement Goal	Noise Improvement Goal (EPNdB)
Zoned Acoustic Liner	Neutral	1.0
Clean Duct	0.3	1.0
Fan Duct Novel Liner	Neutral	Included in Zoned Liner
Low Drag Liner	0.25	Neutral
Short Inlet	0.5 if short Inlet (Neutral if legacy Inlet)	Neutral if short Inlet (0.5 if legacy Inlet)
TOTAL	Short Inlet: 1.05 (Legacy Inlet 0.55)	Short Inlet: 2.0 (Legacy Inlet: 2.5)

2. ANALYSIS AND DEMONSTRATION METHODOLOGY

2.1. ACOUSTIC ANALYSIS

The prediction methodology utilized to assess the performance of the CLEEN II fan duct liner is based on a far-field finite element model developed in ACTRAN combined with a propagation scheme to compute EPNL. For this purpose, a set of experimental static engine test data for the PW1500 engine was adjusted based on the finite element predictions. The ground test data was provided to Collins by Pratt & Whitney as the total and source separated far field measurements. The separated source components included jet noise, aft fan broadband, inlet fan broadband, inlet fan tones, aft fan tones, low pressure turbine and haystack, and combustor broadband. The measurements were provided at representative approach, cutback, and sideline corrected low rotor rotational speeds (RPM). In addition, the test measurements included a baseline (fully treated), and a hard wall configuration (no liner).

The methodology for calculating the EPNL improvement relative to the baseline consists in applying the predicted liner attenuation to the P&W-provided source separated database, specifically to the aft fan broadband and aft fan tones components. All other separated noise source components remain constant. The liner attenuation is applied as a correction to the measured spectra, directly at the microphone location as predicted from the ACTRAN far field model. The corrected data is used instead of full predictions in order to keep the sound directivities as close as possible to the measured noise signature while still accounting for the attenuation improvements due to the advanced liner configuration. The new corrected aft fan broadband and tone components are re-combined with all separated noise sources to re-compute the EPNL using the ANOPP code.

2.2. ACOUSTIC LABORATORY TESTS

In addition to the finite element prediction framework, several test equipment and test facilities have been used during the course of the program to support the development and performance validation of the novel liner concepts. The following is a list of the conducted tests to support the liner development:

- Normal Incidence Impedance Tube (flat samples)
- Aerostructures Flow Duct Facility (insertion loss)
- NASA Grazing Flow Impedance Tube (GFIT)
- NASA LTF / Curved Duct Test Rig (sub-element samples, mode propagation)
- Advanced Noise Control Fan (ANCF – NASA/Univ. Notre Dame – sub-component test, circular segments)
- P&W Ground Test Facility (Standard Static Engine Test [Ref. 1] - planned)

2.3. AERODYNAMIC ANALYSIS

The fuel burn efficiency improvements of technologies which are applied to the engine fan duct can be measured by the change in total pressure loss through the duct. This value is meant to describe the amount of energy loss from the fan to the bypass nozzle, with steps and gaps and obstructions in the ducts removing the energy put into the flow by the fan accelerating air through the duct. The CLEEN II project focused on two major areas of increasing the bypass duct efficiency; a clean fan duct (1) free of obstructions including a removal of the thrust reverser drag links, and steps and gaps from the blocker doors as well as a (2) low drag acoustic liner. These modifications were compared to the production baseline model of the same propulsion system to determine the fuel burn benefits.

Two techniques were used to verify the fuel burn efficiency gains from the CLEEN II technologies. The first was the use of trade factors for the engine, a simple set of relationships that directly correlate the reduction in pressure loss to increased fuel efficiency of the propulsion system. The second technique involved the use of a more complex NPSS propulsion system model built by Georgia Tech's Aerospace Systems Design Laboratory. That model was built off publicly-available data on the CLEEN II PW1500G engine and then verified for accuracy by Pratt & Whitney. GA Tech's model used the total pressure loss reduction in a standard mission profile of the CLEEN II propulsion system to determine the overall fuel burn savings. The conclusions of these two techniques did not differ significantly, validating the use of the trade factors throughout the project.

For liner surface drag, the CLEEN II project sought to reduce the effects of the pressure drag of the perforation by creating low drag liners which made use of smaller diameter acoustic liner holes enabled by Collins' novel perforation developments. A physical model calculating an equivalent sand grain roughness Reynolds number was developed. This model allows utilizing existing models which correlate flow resistance with sand grain roughness by estimating the equivalent roughness associated with perforations. The methodology was validated with test data from NASA and RTRC test facilities.

2.4. DEMONSTRATION PROCESS

The adopted demonstration approach for the inlet and fan duct technologies is illustrated in Figure 2-1. The short inlet demonstration of the aerodynamic and fuel burn benefits was performed based purely on analysis that accounts for the less surface area and lower weight. In addition, the novel acoustic liners were to be demonstrated and validated to TRL 5 via laboratory and sub-component tests on the NASA CDTR facility and the ANCF test rig. For the advanced fan duct demonstration, the approach to reach TRL 6 is to integrate all CLEEN II technologies into a full scale demo and perform a static engine ground test at the P&W C-11 Test Stand. The individual fan duct technologies were incrementally validated through the TRL 3-5 testing (see Section 2.2) in parallel with the CLEEN II program. Unfortunately, due to unfavorable market and economic scenarios given by the COVID-19 pandemic, the acoustic ground test demonstration and the short inlet TRL4/5 testing have been placed on hold and planned for a mid-term future outside CLEEN. Therefore, the demonstration of benefits was solely based on system level acoustic and aerodynamic predictions. Looking out into a future ground test, the original strategy will still apply, and consists on the modification of a production thrust reverser (TR) to incorporate the advanced acoustic liners.

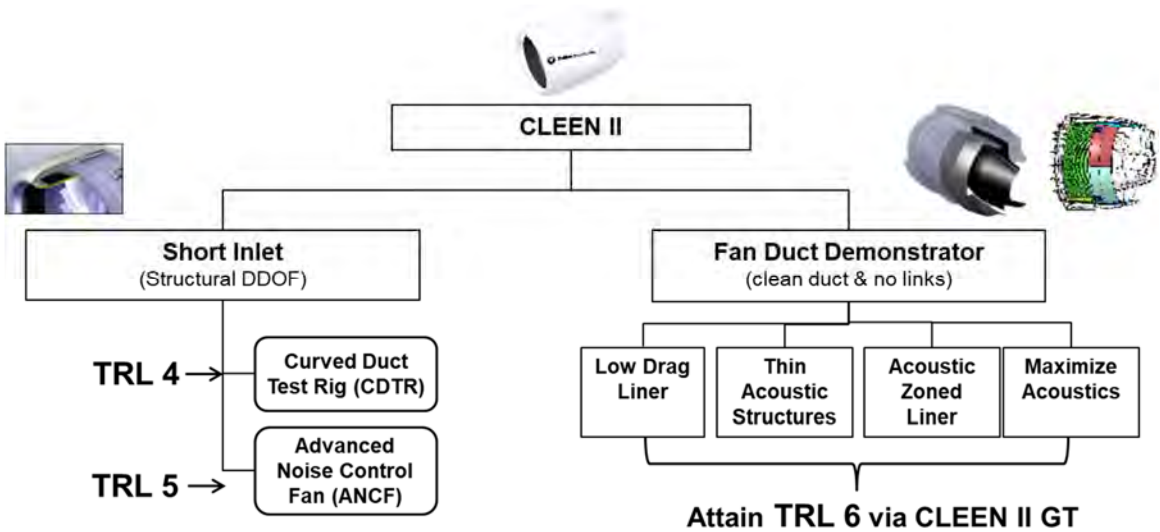


Figure 2-1 Demonstration Scheme.

3. CLEAN FAN DUCT DESIGN

The acoustic design layout of the fan duct acoustic zoned liner is presented. The section includes a brief description of the acoustic optimization, system design, stress analysis and engineering tree.

3.1. ACOUSTICS

An optimization loop was developed in Simulia iSight by RTRC and provided to Aerostructures to perform the liner design. An integral part of this optimization loop is the acoustic liner prediction module, which combines the Aerostructures liner impedance prediction code and a finite element ACTRAN model to compute the zoned liner attenuation. Figure 3-1 shows the basic flow chart utilized by the optimizer. The optimization process provided the liner specifications (core depth, face sheet parameters, etc.) for each of the liner segments to be incorporated in the design.

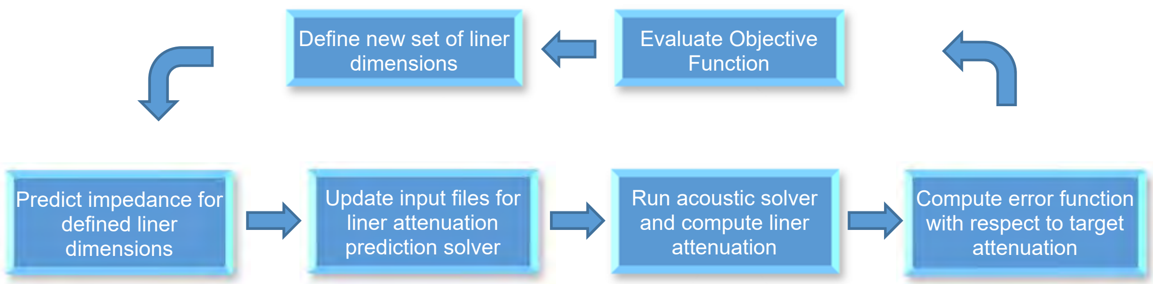


Figure 3-1 Optimization loop flow chart

3.2. DESIGN

A section cut of the overall fan duct acoustic layout is illustrated in Figure 3-2. The design includes three (3) acoustic segments on the outer sleeve, incorporating two zones with the novel core; and five segments on the inner surface including one segment outside of the fan duct (most aft segment). The liner specifications were designed according to the acoustic optimization results. As the duct simulates a clean TR with hidden blocker doors and no drag links, one of the major advantages from the design standpoint is the maximization of acoustic areas. In order to reduce aerodynamic drag in the fan duct, all surface were provided with small hole perforations.

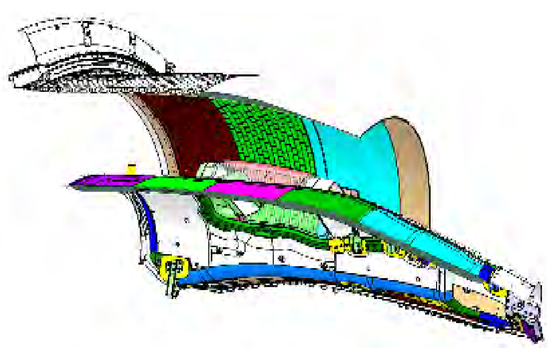


Figure 3-2 Acoustic Zoned Layout of CLEEN Fan Duct

3.3. STRESS ANALYSIS METHODS

This section summarizes the structural modeling and analysis developed in support of the FAA CLEENII Collins Aerospace contribution.

3.3.1. FEM and Loads

A FEM was used to calculate internal forces within the CLEEN II fan-duct given the loading from the production Thrust Reverser model. The stiffness and load paths of the CLEEN II duct are mostly similar to the production TR.

3.3.2. Duct Outer Sleeve

Two new analysis methods were necessary to substantiate the design of the novel core:

- Faceskin buckling
- Lap Shear analysis of the transition from one core-height to another

In addition, the splicing of the novel core segments was verified by test, with corresponding adhesive materials.

3.3.3. Duct Inner Surface

Analysis to accommodate core height transition due to the Zoned Liner was performed. Based on this analysis, suitable core transition ramps are added where varying core depths are required in adjacent acoustic zones.

The flatwise analysis at core height transitions is per Collins Standard Method. Core flatwise compression and core-to-face sheet flatwise tension at the transition location were accounted for in the margin of safety calculation.

3.4. ENGINEERING DRAWING TREE

Ninety (90) new Collins Engineering drawings for inner wall liner parts (referred to as IFS) and 159 new Collins Engineering drawings for outer wall liner parts (XLS) for the ground test TR have been generated and released as of March 2020. The new ground test TR will be manufactured in combination with existing production part drawings and it is defined in Collins Engineering drawing, 501-9300-501, and its top-level drawing tree is shown in Figure 3-3.

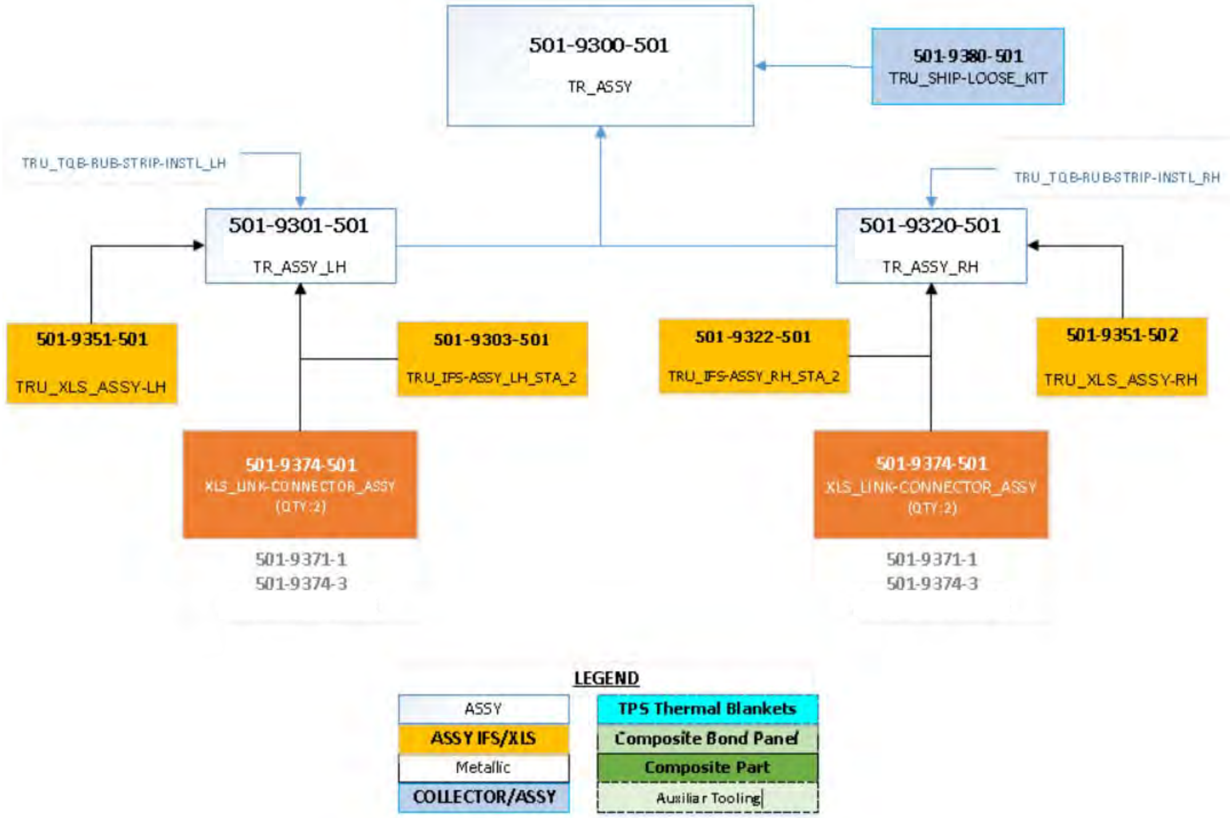


Figure 3-3 Top Level Engineering Tree for CLEEN II Modified TR

4. CLEAN FAN DUCT DEMONSTRATION RESULTS

This section presents the prediction-based assessment of the CLEEN II acoustic fan duct performance. The assessment metric is the calculated EPNL improvement based on the predicted attenuation by each CLEEN II liner technology. As the ground test demonstration of the CLEEN II fan duct has been placed on hold, this analytical assessment serves as the most current measure of the technology performance and benefits, until a ground test validation is performed at a later development program. The following sub-sections summarize the assessment methodology as well as the prediction results.

4.1. PREDICTION-BASED BENEFIT DEMONSTRATION

This section presents the methodology to demonstrate the proposed benefit goals in Table 1-2 and the contribution breakdown of each individual technology.

4.1.1. EPNL Benefits

The EPNL calculations are performed following the process described in Section 2.1, using both ANOPP and P&W legacy code SyLNT for each configuration in Table 4-1.

Table 4-1 Final CLEEN II Prediction Matrix

Cfg #	ID	Description
1	HW	Hard Wall
2	Full Treated	All liners active, zoned configuration, including outside fan duct exit plane.
3	Ducted Treatment	Only in-duct liners active, zoned configuration.
4	Production Liner	Production acoustic area and production liner specifications (Uniform liner)
5	Zoned with Production Area	Zoned Liner configuration on production acoustic area layout.
6	Uniform with Increased Area	Uniform liner on CLEEN II acoustic area layout, in-duct only (no exterior liner)

Based on the configurations in Table 4-1, the EPNL benefits and contribution breakdown of each technology are estimated as:

- Cfg#4-Cfg#2: Overall CLEEN II Fan Duct Benefit
- Cfg#4-Cfg#3: Contribution of In-Duct Treatment
- Cfg#3-Cfg#2: Contribution of Area Outside Duct
- Cfg#4-Cfg#5: Contribution of Zoned Liner (production acoustic area)
- Cfg#6-Cfg#3: Contribution of Zoned Liner (CLEEN acoustic area – in-duct only)
- Cfg#5-Cfg#3: Contribution of added In-Duct Treatment (in zoned configuration)

- Cfg#4-Cfg#6: Contribution of added In-Duct Treatment (in uniform configuration)

Note the HW configuration is only used to compute absolute attenuation.

4.2. EPNL PREDICTIONS

The overall EPNL reduction improvements are calculated relative to a production liner configuration with traditional blocker door thrust reverser and conventional SDOF uniform liner. These EPNL results are reported as the overall benefit of the CLEEN II demonstration package as well as the contribution breakdown of each individual technology. The predicted benefits are also compared to the program goals.

4.2.1. Goals

In order to quantify the benefits, the technology package summarized in Table 1-1 can be grouped into two main contributions for the overall improvement target of 2.0 EPNdB. The two contributions are the new zoned liner layout, which incorporates two segments of the novel acoustic liner, and the additional benefit due to the added acoustic area that would be enabled by a clean surface, next generation thrust reverser. The noise goal breakdown for each contribution is presented in Table 4-2.

Table 4-2 CLEEN II Noise Improvement Targets

Technology Contribution	CLEEN II Goal (EPNdB)
Zoned Liner (including Novel Liner)	1.0
Clean Duct TR with Aft Core Cowl Treatment	1.0
Overall Goal	**2.0**

4.2.2. Breakdown of Technology Contributions

The predicted EPNL benefits and individual technology contributions are presented in this section according to the rationale in Section 4.1.1. The calculations are performed based on the liner attenuations predicted by Collins, and using both the NASA prediction code ANOPP and the P&W in-house code SyLNT. Both results are presented in Table 4-3 and Table 4-4, respectively. The breakdown contributions are consistent for the two methods, but the P&W results yields a smaller overall benefit at 2.2 EPNdB relative to the production configuration, while the ANOPP estimation predicts a 2.7 EPNdB benefit. The two results are shown for comparison, but the P&W estimation should be considered most accurate since it includes the real flight trajectories, proprietary airframe noise, and a validated prediction methodology.

Note that the contribution of the zoned liner and the in-duct added area was evaluated in different scenarios in order to understand the incremental benefit relative to alternative baselines that could be applicable to different nacelle installations. However, for reporting purposes, the estimated benefit is computed as the average of these alternative scenarios.

Table 4-3 EPNL Benefit Breakdown by Technology (ANOPP)

Technology Contribution		Assumption	Relative Comparison	Predicted EPNL Increment (EPNdB)	Estimated Benefit (Average- EPNdB)
Liner type	Zoned Liner	Production Acoustic Area	Cfg4 - Cfg5	1.4	1.1
	Zoned Liner	CLEEN Acoustic Area	Cfg6 - Cfg3	0.8	
Added area	Added Area (In-Duct)	Zoned	Cfg5 - Cfg3	0.5	0.7
	Added Area (In-Duct)	Uniform	Cfg4 - Cfg6	1.0	
	Total CLEEN In-Duct Treatment	Zoned + Added Area (In-duct)	Cfg4 - Cfg3	1.8	**1.8**
	Exterior Liner (Aft Core Cowl)	Out-of-duct area only	Cfg3 - Cfg2	0.9	**0.9**
Total CLEEN II Benefit		Zoned + Added Area Total	Cfg4 - Cfg2	2.7	**2.7**

Table 4-4 EPNL Benefit Breakdown by Technology (P&W SyLNT)

Technology Contribution		Assumption	Relative Comparison	Predicted EPNL Increment (EPNdB)	Estimated Benefit (Average- EPNdB)
Liner type	Zoned Liner	Production Acoustic Area	Cfg4 - Cfg5	1.1	0.9
	Zoned Liner	CLEEN Acoustic Area	Cfg6 - Cfg3	0.8	
Added area	Added Area (In-Duct)	Zoned	Cfg5 - Cfg3	0.5	0.6
	Added Area (In-Duct)	Uniform	Cfg4 - Cfg6	0.8	
	Total CLEEN In-Duct Treatment	Zoned + Added Area (In-duct)	Cfg4 - Cfg3	1.5	**1.5**
	Exterior Liner (Aft Core Cowl)	Out-of-duct area only	Cfg3 - Cfg2	0.7	**0.7**
Total CLEEN II Benefit		Zoned + Added Area Total	Cfg4 - Cfg2	2.2	**2.2**

4.2.3. Overall Benefits and Conclusions

In summary, the contribution of the zoned liner is in line with the target and the added acoustic area seems to provide more attenuation than expected, partly due to the great predicted benefit of the exterior liner (Aft Core Cowl). The overall assessment relative to the CLEEN II goals is presented in Table 4-5. All estimations meet or exceed the CLEEN II goal. The P&W estimation of the zoned liner contribution barely misses the target by 0.1 EPNdB, but it is compensated by the additional area, making the overall total benefit be slightly over the requirement.

In conclusion, the overall CLEEN II acoustically optimized fan duct configuration meets the program targets, while these result remain to be validated at a later date by ground testing.

Table 4-5 EPNL Benefit Breakdown by Technology (P&W SyLNT)

Technology Contribution	CLEEN II Goal (EPNdB)	Collins Assessment (ANOPP)		P&W Assessement (SyLNT)	
Zoned Liner (inlcuding Thin Acoustics)	1.0	1.1	Meets Req	0.9	Marginal OK
Clean Duct TR with Aft Core Cowl Treatment	1.0	1.6	Exceeds Req	1.3	Exceeds Req
Overall Goal	**2.0**	**2.7**	**Exceeds Req**	**2.2**	**Meets Req**

4.3. FUEL BURN RESULTS

4.3.1. Clean Duct Benefits

The steps and gaps removed by the clean fan duct design resulted in a DP/P decrease of 0.016% from the removal of the blocker doors and decrease of 0.08% for the drag links, bases and fittings. This translated to a reduction of 0.19% SFC which in turn resulted in a fuel burn reduction of 0.21%. DP/P values were converted from the to the fuel burn benefit by the trade factors given by Pratt & Whitney for the PW1500G.

4.3.2. Low Drag Liner Benefits

The drag reduction from the low drag perforation effected the bypass by decreasing the pressure delta through the duct. Using the effect of perforation drag from the baseline design of the PW1500 propulsion system, the CLEEN II team determined that a reduction in drag was directly proportional to a reduction in pressure loss through the duct. Therefore, because the experiments performed in the test facilities showed that micro-perforations replacing the current baseline perforation would correspond to a 50% reduction in drag, it was found that the CLEEN II design could achieve a 50% reduction in pressure losses through the bypass duct. This corresponded to a fuel burn benefit of 0.25%.

4.3.3. Overall Benefits

In total the benefits of a clean fan duct and low drag liner combined to generate a fuel savings of 0.46%. This was assuming that both improvements acted independently from one another which was consistent with our own experience with both these technologies. Additionally this result correlates well with validating work done by the Georgia Institute of Technology for the same improvements on the same platform which showed a fuel burn benefit of 0.43%.

5. INLET DEMONSTRATION RESULTS

This section summarizes the efforts in support of the short inlet development. Both the aerodynamic assessment and the acoustic initial efforts will be discussed.

5.1. AERODYNAMIC BENEFITS

Fuel savings benefits derived by the short inlet architecture fall into two categories; weight reduction from the removal of structure and reduced skin friction drag due to extended laminar flow on the surface. The CLEEN II study assumed inlets with laminar flow extended to aft end of outer inlet cowl. This was achieved via deep draw lip skins, specialized joints that did not trip the flow to the turbulent regime and specialized surface treatments that would mitigate the effect of small excrescences. The reduction in drag accounted for a fuel burn reduction of 0.35%.

In addition, the inlet was shortened from the baseline L/D (Length of Inlet/ Diameter of Fan Face) of 0.6 to an L/D of 0.4. This change resulted in a fuel burn savings of 0.15% determined via the delta of weight between the two designs and the trade factor which converts weight of propulsion system to the equivalent fuel burn for the PW1500G. Overall, the short inlet fuel burn reduction is 0.5%.

5.2. ACOUSTICS EFFORTS

The focus of the short inlet acoustic efforts has been the development of advanced liner concepts targeting equal or better performance than current state-of-the-art DDOF, at significantly lower cost, to enable shortening the inlet without acoustic impact.

Since the inlet architecture does not require reduced thickness acoustic panels, the investigated concepts allow for having multiple layers that act as DDOF or MDOF systems. The evaluation of initial concepts was conducted in the Chula Vista Flow Duct facility in order to understand the frequency range capabilities of these new concepts. The measurements were qualitatively compared to a production representative DDOF liner panel, which led to the down-selection of a novel configuration consisting of large acoustic cavities combined with traditional honeycomb core. The total thickness of the panel was comparable to the production DDOF liner. The selected concept was investigated by focusing on manufacturing variations that enable feasibility and low cost production. To this end, Aerostructures is closely working with a supplier that can address these challenges while still providing a manufacturing competitive product. The technology is currently at TRL/MRL 3 with completed coupon trials, but unfortunately, these efforts have been put on hold for the remainder of the CLEEN II program and will be resumed in 2021.

Once the development resumes in 2021, the manufacturing trades will continue towards defining the most viable liner configuration and subsequently validating its performance through Collins standard process for TRL development. This process includes test campaigns in the NASA LaRC CDTR (Curved Duct Test Rig) followed by tests at the NASA ANCF Rig, operated by the University of Notre Dame Turbomachinery Lab.

6. MANUFACTURING EFFORTS

From late 2018 to early 2019, process mapping and manufacturing flow events were held with manufacturing teams in Riverside, CA and Foley, AL. Following the engineering drawing tree and process maps, fabrication planning was developed, and planning books were issued to respective R&T laboratories and production stations. The fabrication of the ground test TR was split among three Collins Aerospace locations as shown in Figure 6-1.

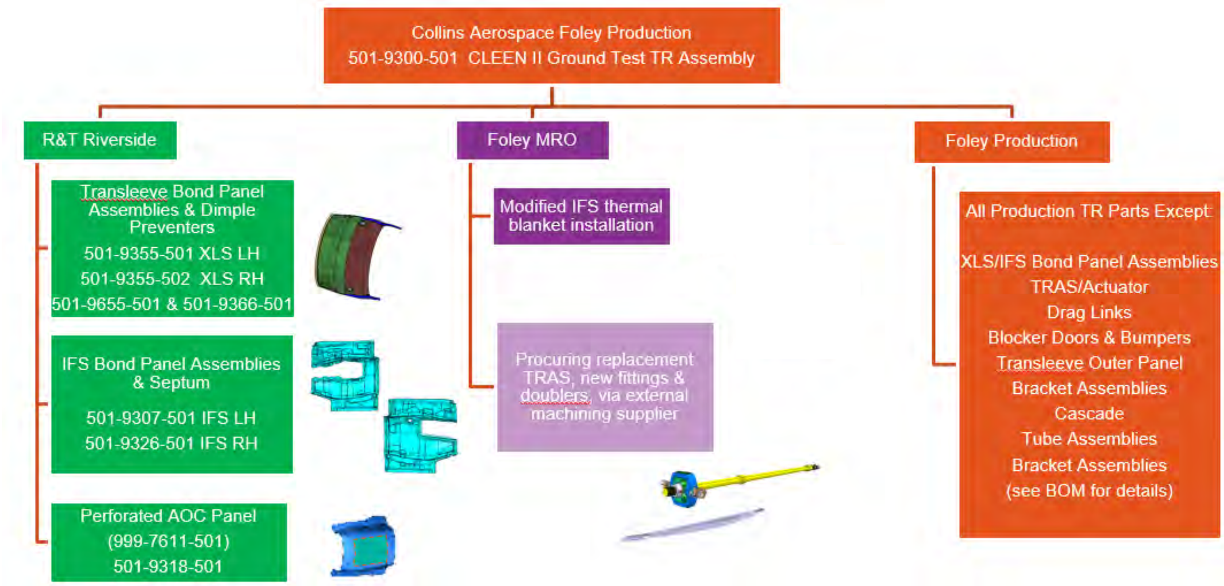


Figure 6-1 Manufacturing plants to support CLEEN II Demo Build.

The manufacturing of all new acoustic bond panels was performed in Riverside, CA, while the integration into the production TR was planned for Foley, AL. In Riverside, a right hand inner wall liner and an AOC fairing bond panel were completed. Perforated skins for the right and left outer wall liners and the left hand inner wall liner were also produced. In addition, Nover Core parts for the outer wall liner were also manufactured. The next sub-sections provide highlights about the final products. Since the ground test efforts are on hold, the assembly and modification procedures planned for Foley have been halted.

All manufacturing has been performed per existing, released Rohr Materials Specifications (RMS) and Rohr Process Specifications (RPS).

6.1. PERFORATION TECHNOLOGIES

Perforation of the inner and outer wall bond panel skins was performed by an automated perforation technology (APT). All APT perforations exhibit excellent hole quality and are very close to nominal POA specifications.

6.2. FAN DUCT NOVEL LINER

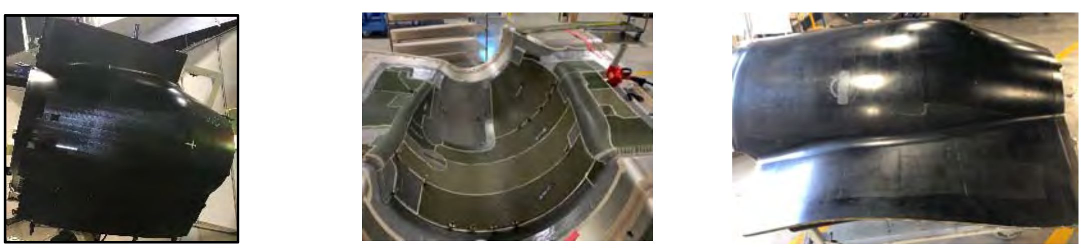
Core fabrication supporting the ground test TR was completed in October of 2019. Post fabrication manual operations were performed for the one-off CLEEN II unit, and 75% complete by May 2020. This will resume when the ground test is potentially restarted in 2022. Currently, Collins is working to develop a fully automated process without post-fabrication manual adjustments. Additional components to complete the liner assembly were completed prior to March 2020. All manufacturing and assembly tooling for the novel liner were procured by January 2020.

6.3. ZONED LINER

This section presents manufacturing efforts supporting the zoned liner design described in Section 3.2. A right-hand fan duct inner wall liner was completed. All other components, except for 25% of acoustic core have been fabricated but not assembled as an acoustic liner. These acoustic liners will be fabricated at a future date. In addition, an AOC panel has been completed. All fabricated zoned liner panels and components will be stored in a locked crate along with the fabrication planning books as of December 2020. The following sub-sections describe the progress.

6.3.1. Fan Duct Inner Wall Liner

The manufacturing of the inner wall zoned liner was performed in three steps: skin perforation, bond panel lay-up, and cure. A trial perforation began in September 2019 followed by perforation of actual ground test skins in February 2020. All skins for inner and outer surfaces were completed in May 2020 following the zoned liner requirements from Section 3.2. The right hand inner liner panel was then combined with the core layout (also supporting the intended segmented configuration) and final assembly was complete in August 2020. The manufacturing process is illustrated in Figure 6-2. All other fabricated components supporting the left hand inner surface and both outer surfaces will be stored for future use.



(a) *(b)* *(c)*

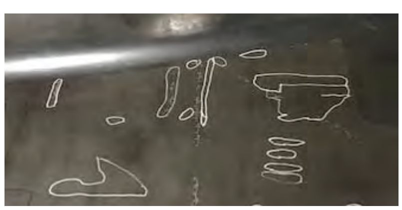
Figure 6-2 Fan Duct Inner Surface Liner Manufacturing: (a) Skin Perforation, (b) Bond Panel Assembly, (c) Final Acoustic Panel.

In addition, the AOC acoustic panel, used as a small portion of the left hand inner wall liner, was also produced and it is depicted in Figure 6-3.

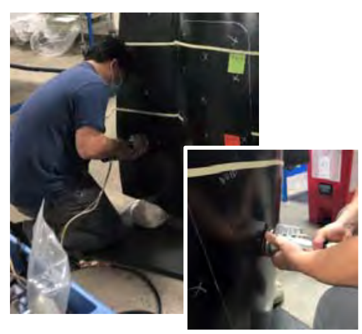
Figure 6-3 Acoustic ACOC fairing panel.

6.3.2. Inspections and Repairs

Inspections were conducted to verify the structural integrity of the panel as well as the acoustic specifications. Acoustic quality was verified through visual inspection of adhesive blockage, geometric (pin gauge) inspection of percent open area (POA), and acoustic impedance, following an inspection plan specifically developed for this unit. Overall, the quality of the panel was satisfactory and presented small defects commonly found in production programs. In terms of hole blockage, there was a few scattered areas that required manual drilling to clean excessive adhesive that migrated to the holes during curing operation. Even though plans are in place for improvement, the extent of the affected areas was quite small and very encouraging given the small size of the low drag perforations. The POA was compliant on all segments except for one small area on the upper bifurcation surface. This area was also manually re-worked to recover nominal properties. Impedance testing revealed favorable results for all segments. Finally, the structural integrity was verified by C-Scan, which revealed a small area that also required repair. All repairs were conducted using standard procedures coordinated with traceable documentation. After repair, the unit was compliant to all specifications. Figure 6-4 illustrates the visual hole blockage and impedance inspections.



(a)



(b)

Figure 6-4 (a) Visual Hole Blockage, and (b) Impedance Test Inspections

7. TECHNOLOGY READINESS SUMMARY

7.1. LOW DRAG LINER

Low Drag Liner technology, developed to provide lower surface drag than legacy perforated acoustic panels, reached a technology readiness level of 5 and a manufacturing readiness level of 4 in March 2017. CLEEN II had plans to progress low drag liner development for TRL/MRL 6 via the inner wall zoned liners (5 segments) and sleeve zoned liners (3 segments) in ground test unit. Meanwhile, a production program adopted CLEEN II LDL technology using automated mechanical drilling of small holes for the Aft section of the thrust reverser. TRL 6 was achieved via successful implementation on first production unit, which tested compliant to all acoustic specifications approved by the customer. TRL 7 is expected as full production begins in Q2 2021.

7.2. FAN DUCT NOVEL LINER

The fan duct novel liner secured a technology readiness level of 5 and a manufacturing readiness level of 4 in March 2017. This readiness level was achieved through the following focus areas: Design, Stress and Acoustic Analysis, Prototype Liner fabrication and repair, and Test at NASA GFIT which validated acoustic properties and prediction models. The progression to TRL/MRL 6 is still planned via the liner demonstration for the ground test unit, but it has been placed on hold for future work.

7.3. ACOUSTIC ZONED LINER

Acoustic Zoned Liner technology, a purposely segmented impedance configuration targeting an acoustic optimized duct, reached a technology readiness level of 5 and a manufacturing readiness level of 4 based upon completion of acoustic tests at the NASA ANCF (Advanced Noise Control Fan) Rig operated by the University of Notre Dame Turbomachinery Laboratory, in September 2017, and subsequent validation of prediction models. A picture from the ANCF test program is provided in Figure 7-1. The test configuration consisted of a 2-segment zoned liner. All manufacturing efforts presented in Section 6, have contributed to achieving TRL6/MRL6.

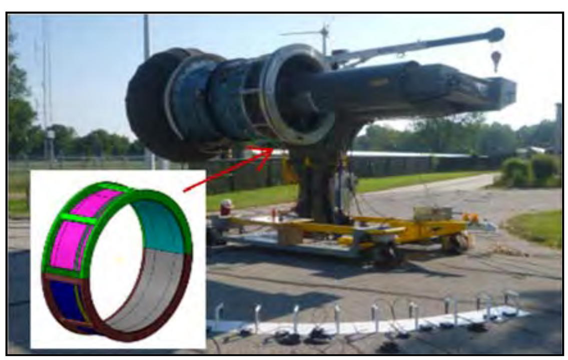


Figure 7-1 Simulated Acoustic Zoned Liner at the NASA ANCF Rig

In parallel to CLEEN, Collins Aerospace successfully achieved TRL6/MRL6+ for a low drag zoned liner via implementation in a production program. The design targeted uniform impedance across the fan duct inner surface while segmenting the liner for the sole purpose of reducing drag. The first, most forward zone, is built to the original standard hole specifications, and the second, aft zone, was modified with a smaller hole size. This configuration is planned to achieve TRL 7 with first commercial flight and full production in Q2 of 2021.

7.4. CLEAN DUCT AND EXTERIOR LINER

The acoustic area layout developed during CLEEN II simulated a clean duct surface that is envisioned for future compact nacelle architectures. While the thrust reverser mechanisms for these future platforms remains with low maturity, the integration of acoustic liners into continuous nacelle internal surfaces is quite mature and can be achieved by using legacy production methods.

The exterior liner concept is an essential element to support the future development of a clean duct TR for compact nacelle applications. As described throughout this report, the type of acoustic liner envisioned for an exterior surface is an aft extension of treated surface on the inner wall of the fan duct. As mentioned above, all manufacturing processes for this liner are state-of-the-art and production-ready with minimal risk for implementation. The technology maturity, including industrialization and certification, is quite elevated at TRL/MRL9. Nonetheless, efforts to formally quantify the value of placing acoustic liners on exterior surfaces are needed to justify the increased complexity, cost, and trades with other competing requirements. In other words, a ground test validation is not necessarily tied to TRL demonstration but instead, it allows the industry gain justification for implementation. Collins will continue to consider opportunities for this demonstration, including possibly resuming plans for ground testing on the PW1500 engine.

7.5. SHORT INLET ACOUSTICS

Short Inlet Acoustic technology, which combines structural DDOF, Low Drag Liners, and Inner Barrel perforation reached a technology readiness level of 3 and a manufacturing readiness level of 3, with its DDOF prototypes fabricated and tested, in September 2018.

While down selecting primary concept in Q4 2019, producible core selection led to study core configuration closely as manufacturability once again proved to be the main challenge. In September 2019, an assessment was completed for fabrication feasibility. During this time 3 demos were produced using material readily available. Resulting data allowed this method to progress in TRL/MRL 3 in November 2019. After this efforts, it was determined that further modification were required in order to achieve a lower cost, more competitive solution. As of February 2020, a clear path to development was identified. Although progression showed high potential for a new Aerostructures product, COVID-19’s resource reduction/budget constraints delayed further progression. Once the effort resumes, the next steps will be towards incremental validation using the CDTR (Curved Duct Test Rig) followed by ANCF (Advanced Noise Control Fan) testing into 2021 and 2022, respectively.

8. PROGRAM CONCLUSIONS

Advanced technologies have been developed by Collins Aerospace – Aerostructures in support of aerodynamically and acoustically optimized nacelle systems, enabling lower emissions, energy and noise, aimed at the next generation of high bypass ratio propulsion systems for reducing climate impact from aviation. The overall technology suit included novel acoustic configurations for both the inlet and fan duct. Even though it was not possible to execute the planned acoustic ground test demonstrations, the program generated sub-element laboratory test data and advanced prediction tools that allowed quantifying and demonstrating the proposed benefits analytically. In addition, the manufacturing maturity of both inlet and fan duct acoustic technologies was significantly advanced by the efforts facilitated by the CLEEN II program and documented in this report. Selected technologies from the program, e.g. low drag surfaces and zoned liner configurations, have successfully reached production ready status and have been incorporated into current production nacelle applications. Also, the acoustic optimization tools developed in support of CLEEN II have been incorporated into Aerostructures standard processes for liner optimization.

The prediction-based assessment of the advanced TR acoustic benefits included the EPNL calculations based on the predicted attenuation levels for the advanced liner configurations. The investigation included the overall assessment of the full treated system and the contribution of each individual technology being demonstrated, e.g. clean duct added treatment and zoned liner. The liner was designed and optimized by the acoustics R&T group at Aerostructures, in collaboration with the Raytheon Technologies Research Center (RTRC) that developed the optimization software. In summary, it was concluded that the overall EPNL benefit as well as the individual contributions of the liners are in line with the targets and meet the CLEEN II noise improvement goal of 2.0 EPNdB. The liner performance suggests that the overall system has similar behavior as a DDOF system. As the ground test demonstration of the CLEEN II fan duct has been placed on hold, the completed analytical assessment serves as the most current measure of the technology performance and benefits, until a ground test validation is performed at a later development program.

For the inlet liners, only qualitative screening tests were conducted, showing great potential to improve attenuation of legacy DDOF liners. However, further demonstration tests for inlet liners was left for future work.

Total fuel burn benefits of the clean fan duct and low drag liner combined to generate a fuel savings of 0.46%. This was assuming that both improvements acted independently from one another which was consistent with our own experience with both these technologies. Additionally this result correlates well with validating work done by the Georgia Institute of Technology for the same improvements on the same platform which showed a fuel burn benefit of 0.43%. The inlet length reduction resulted in a fuel burn savings of 0.5% determined via the delta of weight between the two designs and the trade factors.

In addition, significant progress was achieved on the manufacturing maturity of the advanced liner configurations. Small hole laser perforation methodology has been scaled up to full scale nacelle parts and provided excellent quality holes relative to the nominal POA specifications, including the ability to create a zoned layout. The perforation technique was successfully used to perforate all CLEEN II skins. Novel core fabrication that supported the ground test TR was completed using advanced proprietary fabrication. For zoned liner manufacturing demonstration, a right hand inner wall liner was completed as of November 2020. An AOC panel to be combined with the left hand inner wall surface was also completed. However, as aforementioned COVID-19 impact on CLEEN program at Collins

Aerospace, the fabrication of the rest of acoustic liners will resume followed by the TR assembly after the acoustic ground test schedule is reassessed in late 2022. Meanwhile, previously fabricated parts including but not limited to perforated skins, procured/machined cores, composite accessories, etc. along with fabrication planning books, will be securely stored for the future fabrication at Collins Aerospace in Riverside, CA.

For inlet liner, the major manufacturing breakthrough from the program was the establishment of a collaboration agreement with a core supplier, which gives Collins a clear path to achieve competitive manufacturing process when efforts resume in 2021.

9. ACKNOWLEDGEMENTS

This work has been performed under the Federal Aviation Administration's (FAA) contract DTFAWA-15-A-80015 and the no-cost extension to December 2020 under DTFAWA-15-A-80015 P00006, to support the "Continuous Lower Energy, Emissions and Noise" (CLEEN II) program submitted by Aerostructures (Collins Aerospace) in response to FAA's Screening Information Request (SIR), DTFAWA-14-R-73573. FAA's funding support of these activities is greatly appreciated.

The inter-company collaboration with P&W has been under Collins Statement of Work (SOW), MP 16-UTAS-001, the proposal MP 18-036, and associated Inter-entity Work Authorizations (IWA), e.g. the latest is IWA49380. We would like to thank the program manager, John Kiernan, the ground test manager, Michael Trudnek, and their P&W associates for the support from the start of CLEEN II project. In addition, we would like to thank Paul Schweiger for his technical support for conducting EPNL acoustic assessments.

Collaborations with Raytheon Technology Research Center (RTRC; former UTRC) have been conducted under respective IWAs. We would like to acknowledge acoustics engineers Kenji Homma and C. Aaron Reimann for their great contributions for prediction tool developments.

The collaboration with GTRC has been conducted under a Non-Disclosure Agreement signed between Rohr, Inc. and Georgia Tech Research Corporation (GTRC) on January 13, 2016 and its 3-year extension signed in June 2019.

Lastly, accomplishments of this project are greatly contributed by dedicated Collins Aerospace colleagues at R&T Lab, APT Lab, QA, and the production in Riverside, CA, design and analysis support in Chula Vista, CA, and the assembly planning support in Foley, CA as well as project and manufacturing engineers, management, and SCM at all three facilities for coordinating and cooperating.

10. REFERENCES

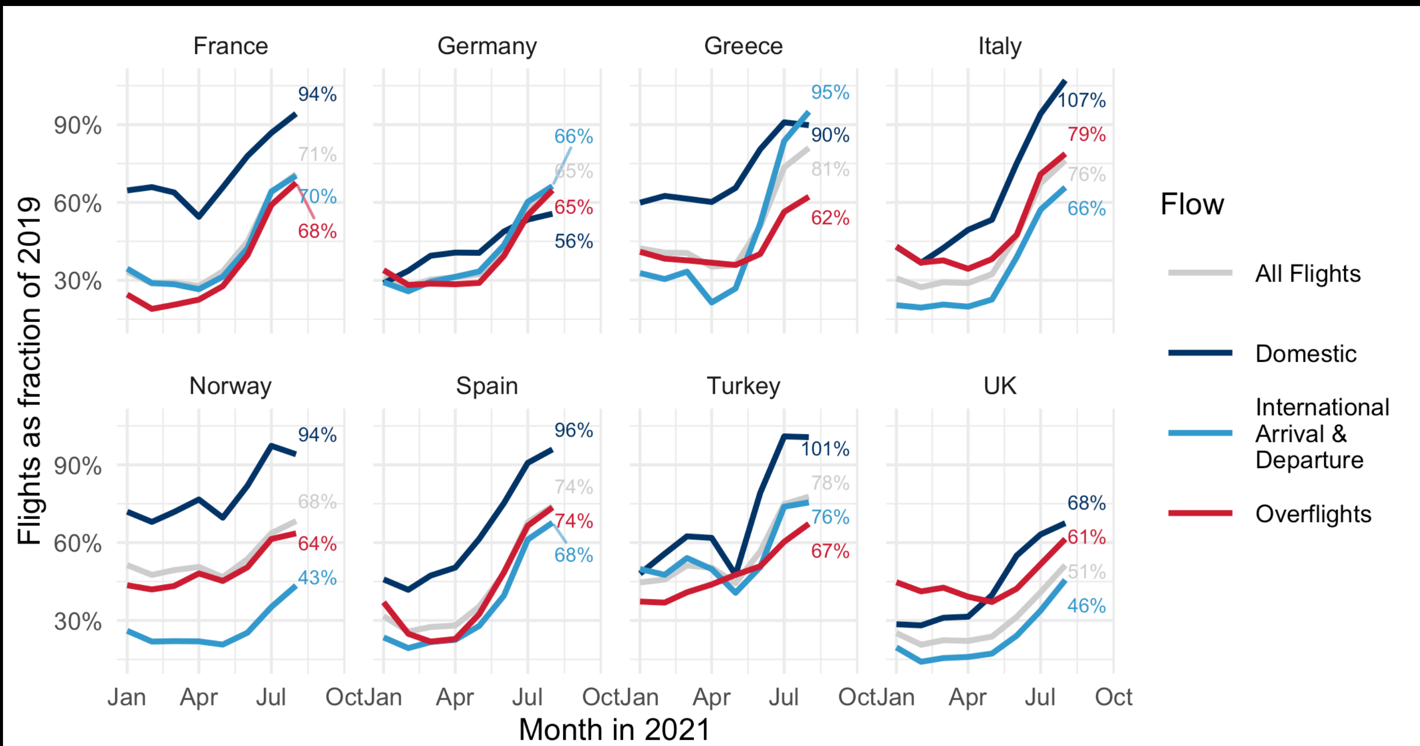
1. ARP 1846A, ‘Measurement of Far Field Noise From Gas Turbine Engines During Static Operation,’ March, 2008.

EUROCONTROL Data Snapshot

The recovery this summer to 70% of 2019 flights conceals wide variations.

EUROCONTROL

7 September 2021



In August, flights were back to 71% of 2019 levels across Europe. This average, however, conceals a wide variation between countries and also between different traffic flows for each country. The graphic illustrates this variation, taking examples from some of Europe's larger aviation markets.

We noted in a data snapshot in March that domestic flights were holding up better during the pandemic than international flights. This summer, that trend has continued. Turkey, indeed, exceeded 2019 domestic flight counts already in July. Then Italy beat that in August, reaching 107% of 2019, with France, Greece, Norway and Spain all at 90% or more. In the graph, German domestic flights stand out by being overtaken by other flows.

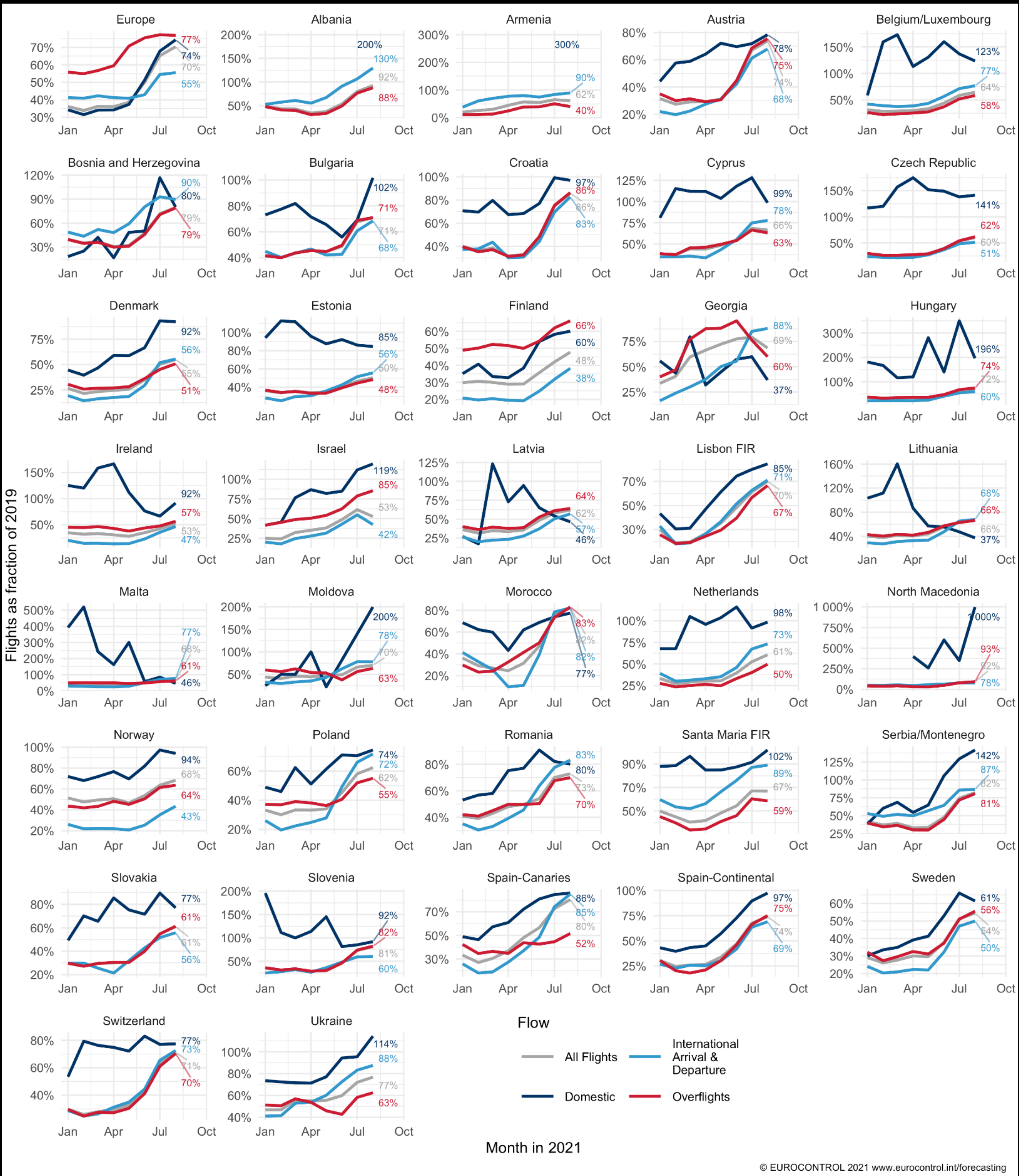
International arrivals and departures include long- and short-haul, and both passenger and cargo flights. COVID-19 passenger travel restrictions have mostly affected international passenger flights and this is reflected in the relatively low figures for international flights (as compared to domestic ones). From the graph, UK and Norway remain particularly weak on this flow: still less than half of 2019 levels. Key holiday destinations, on the other hand, saw a rapid recovery in July and even more in August.

Overflights, not touching an airport in the country, often make a significant contribution to revenues of a country's air navigation service provider. The UK has the weakest overflights of these eight countries, with both Ireland and North Atlantic, which make up most of this flow, slow to recover. Italy and Spain are much stronger, with a strong acceleration starting in July; for example, Italy picked up flights from France and Switzerland to Greece, both of which are already above 2019 counts.

Technical Bits: Daily updates on flights in general are available here. The selection of countries in the graph was both by size and geographical spread. Other countries and flight regions are available in the accompanying spreadsheet, and shown overleaf.

EUROCONTROL Data Snapshot

EUROCONTROL



SUPPORTING EUROPEAN AVIATION

FOUNDING MEMBER SESAR JOINT UNDERTAKING

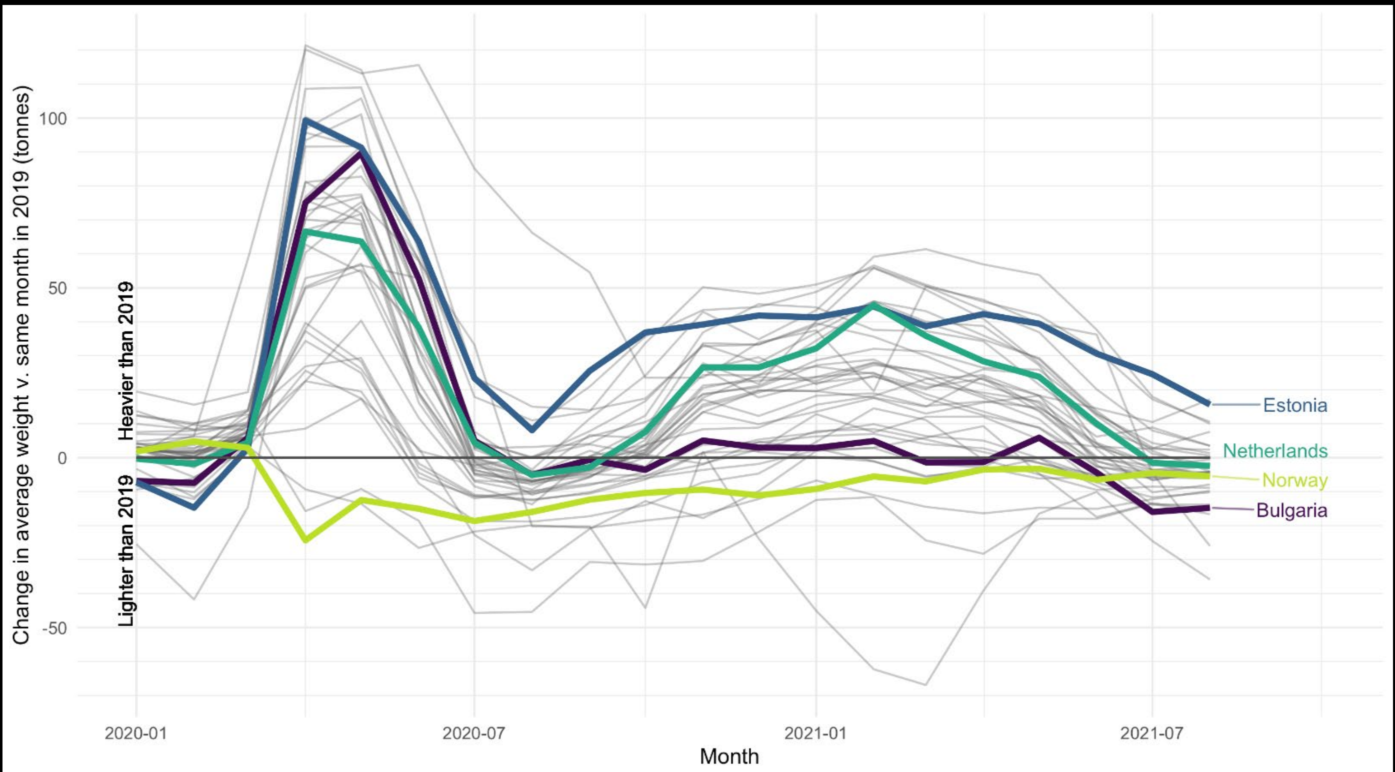
NETWORK MANAGER

EUROCONTROL Data Snapshot

Most countries saw heavier aircraft during COVID19. This is returning to normal, but that reduces ATC revenue even further.

EUROCONTROL

21 September 2021



In a recent snapshot we explored how flights have recovered at different rates in different countries. Another source of variation is in the types of aircraft seen, which is represented in this chart by changes in average weight. These weight changes tell a story about the balance between long-haul and short-haul, and between cargo and passenger flights.

Heavier aircraft also mean higher revenues for air navigation service providers. Weights were very high between March and June 2020 (see spike in chart). This partly made up for the revenues lost due to cuts in flights, although in most cases it only marginally reduced the financial impact due to the substantial decline in flights. In early 2021, many countries saw average aircraft weights 20-50 tonnes higher than in the same period in 2019. (In normal times, a change of around 2 tonnes between one year and another would be more usual.) Now that weight gain is coming to an end.

Estonia has seen large weight gains for much of 2021, with its Baltic neighbours in a similar position. This reflects the continuing strength of cargo overflights (25% above August 2019), compared to total flights (*down* by 50%). So this shows both the strength of long-haul cargo (to Russia and to North and East Asia), and the rarity of passenger flights to the same destination. With the Summer's traffic recovery, the weight gain has diminished.

In contrast, Bulgaria and some of its neighbours have seen little increase in weight compared to 2019. Flows of long-haul, heavy aircraft to the Middle East and South-East Asia, especially from the UK, are weak. And still, in the last months, average weights have declined, cancelling out some of the revenue benefits from the recovery in flight numbers.

Norway has been seen in several snapshots as an outlier, with its strong domestic flows. This is reflected also in the average aircraft being lighter for most of the period (few of the heavy long-haul aircraft, relatively more lighter, short-haul aircraft). Finally in the chart, the Netherlands stands for the many countries which had much heavier aircraft last winter, but where the mix of aircraft is closer to normal this Summer.

Technical Bits: Monthly updates on flights, weight and distance, as they relate to revenue of air navigation service providers are available in the CRCO Dashboard.

EUROCONTROL

Greening European ATM's ground infrastructure:
What could ANSPs achieve over the next decade?

If aviation is to achieve its ambitious decarbonisation goals, as the sector takes on the challenge of achieving carbon neutrality by 2050, all emissions sources need to be considered. This Think Paper argues that there is considerable potential to 'green' the ground infrastructure of European air traffic management (ATM) – its control towers, control centres, offices and other essential ground facilities – over the next decade.

In this Think Paper we make a very first assessment of the extent of Europe's ATM ground infrastructure, and use this to assess its potential to contribute to the overall goal of aviation decarbonisation.

We ask:

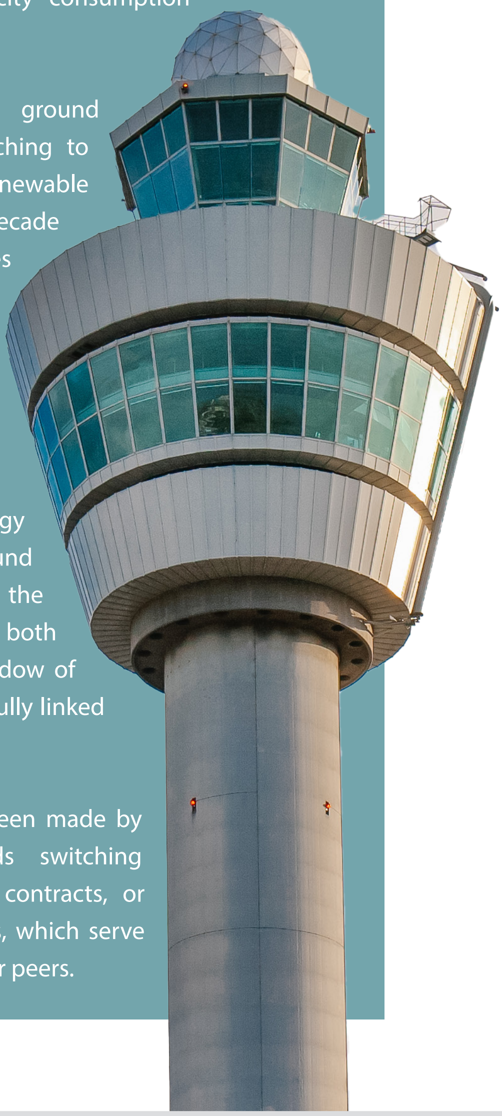
- How much electricity does Europe's ATM ground infrastructure consume, and how many tonnes of CO_2 emissions are generated as a result?
- What initiatives are air navigation service providers (ANSPs) already taking to reduce their energy consumption?
- What impact would switching to renewable energy have on the carbon footprint of ATM ground facilities?

We conclude that **decarbonising European ATM's ground infrastructure** could deliver **large potential emissions savings on an annual basis,** providing strong support to aviation's overall decarbonisation goals.

For this to happen, ANSPs would need to **seize the right moment in their investment cycles** to replace energy-inefficient equipment, and to **accelerate the switch to renewable energy sources.**

MAIN FINDINGS

- European ANSPs are estimated to consume **1,140GWh** of electricity annually, roughly equivalent to 55% of the annual electricity consumption of Malta.
- Decarbonising this ground infrastructure by switching to and investing in renewable energy over the next decade could save **311K** tonnes of CO_2 equivalent emissions annually, summing up to over **6.2M** tonnes overall by 2050.
- Improving the energy efficiency of all ground infrastructure over the next 10 years will be both a challenge and a window of opportunity if successfully linked to investment cycles.
- Progress has already been made by some ANSPs towards switching to renewable energy contracts, or greening their facilities, which serve as best practice for their peers.



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How much air navigation services (ANS) infrastructure is actually out there?

European ATM has an **extensive air navigation services infrastructure that is largely organised along State boundaries,** as Figure 1 sketches out:

FIGURE 1: PAN-EUROPEAN ANS NETWORK [1]

37 air navigation service providers (ANSPs)

62 area control centres (ACCs)

279 terminal area & airport approach control facilities

406 airports with ATC services (most with a control tower)

A recent EUROCONTROL Economic Perspective study[2] estimated that there are in addition **well over 6,000 CNS (communications, navigation and surveillance) ground-based facilities across Europe** (see Figure 2). **Further optimisation of the European CNS infrastructure clearly has the potential to reduce energy consumption and emissions**, and the need to estimate such savings has led to the development of this Think Paper.

FIGURE 2: ESTIMATED CNS FACILITIES IN EUROPE

SERVICE	SES Area	ECAC Area
COM	588	891
NAV	2797	3694
SUR	1720	2059
TOTAL	**5105**	**6644**

Can we estimate the electricity consumption of the facilities that make up the ATM/CNS ground infrastructure?

This Think Paper makes a series of assumptions based on an assessment of the scope of the known or estimated infrastructure – with some caveats based on the nature of the main types of facility.

On the communications side, many facilities have to be kept in a specific temperature range to function as guaranteed, requiring air conditioning which adds additional power consumption. Thus, for a communications antenna, its power use is likely to be substantially less than its air conditioning unit. On the other hand, the power consumption of a primary radar station emitting electromagnetic pulses, including all the electronics and rotating elements, will be substantially greater than any air conditioning it may require.

For communications equipment in particular, it may be impossible for an ANSP to isolate the power consumption of an antenna if it is located on top of a building operated by a third party. This could be the case at an airport, where such antennae could be on terminal buildings or other facilities. An ANSP could also benefit from siting equipment at secure facilities controlled by government departments, but thus with no visibility on the energy consumed.

For navigation and surveillance facilities, their nature as single-purpose installations only developed for and operated by air traffic control should make it easier to calculate individual energy consumption; this information is not however publicly available, since facilities' performance requirements are generally covered in confidential supplier contracts.

Estimating ANSPs' energy consumption therefore requires a different approach. Some ANSPs do publish annual aggregated energy consumption data, and this Think Paper uses this to develop a ballpark figure.

We looked at a large sample of ANSPs' annual and sustainability reports, finding four ANSPs – ENAV, NATS, NAVIAIR and skyguide – reporting their overall electricity consumption, as per Figure 3.

FIGURE 3: TOTAL REPORTED ELECTRICITY CONSUMPTION OF SELECTED ANSPs*

ANSP	2020 consumption
ENAV	67.0 GWh
NATS	60.0 GWh**
NAVIAIR	6.8 GWh
Skyguide	11.0 GWh

Notes: **See ANSP reports at 3, 4, 5 & 6*
***2019-2020 data*

"This Think Paper takes a different approach to estimating ANSPs' energy consumption, to develop a first-ever ballpark figure"

A recent article[7] has estimated that the ATC towers at two medium-sized airports, together handling approximately 80,000 air traffic movements annually, could together expect to generate 170 tonnes of CO_2 equivalent emissions. The ATC towers at the airports in question, Larnaca and Paphos on Cyprus, averaged almost 300MWh of electricity consumption annually. If this is representative of airports with roughly 40,000 annual movements, an ANSP running 10 such towers may require 3GWh of electricity to operate them.

However, **an ANSP's carbon footprint is wider than its area control centres (ACCs) and control towers (TWRs), with headquarters and regional offices to be taken into account as well as CNS infrastructure.**

We estimate that a medium-sized ANSP running one or two ACCs, up to ten airport towers, an HQ and regional offices, as well as CNS and other facilities, could consume somewhere in the range of 20GWh of electricity annually. **Actual consumption will also be influenced by geography and climate, as well as the number of staff employed, which can be thought of as a proxy for the built office space and, by extension, ANSPs' energy consumption.**

However, ANSPs vary considerably in terms of number of ACCs, towers and staff, as Figure 4 reveals.

FIGURE 4: 10 LARGEST ANSPs IN TERMS OF STAFF COMPLEMENT [8]

COUNTRY	ANSP	#ACCs	#TWRs	#Staff
France	DSNA	5	75	7622
Turkey	DHMI	2	51	6894
Germany	DFS	4	16	5095
United Kingdom	NATS	3	14	4312
Ukraine	UkSATSE	4	16	4287
Spain	ENAIRE	5	21	3944
Italy	ENAV	4	16	3063
Poland	PANSA	1	15	1899
Greece	HCAA	1	18	1650
Romania	Romatsa	1	16	1613

In order to estimate total energy consumption across European ANSPs, we clustered them according to the numbers of their ACCs, TWRs and staff, and used a combination of linear fit and expert judgement to allocate an average annual consumption to the ANSPs in each cluster as follows: Very large – 110GWh; Large – 65GWh; Medium-large – 30GWH; Medium – 20GWh; Medium-Small – 15GWh; Small – 12GWh.

Manual adjustments were applied where the number of ACCs, TWRs or staff were outside the ranges defining a cluster, resulting in a small number of ANSPs being reallocated. Figure 5 shows the final clustering.

FIGURE 5: EUROPEAN ANSPs CLUSTERED ACCORDING TO ACCs, TWRs & STAFF

CLUSTER	ACCs	TWRs	STAFF	SERVICE PROVISION	TOTAL
Very large	2-5	>50	>5000	France, Turkey	2
Large	2-5	15-25	2000-5000	Germany, Italy, Spain, Ukraine, United Kingdom	5
Medium-large	1-2	15-20	1000-2000	Greece, Norway, Poland, Romania, Sweden	5
Medium	1-2	10-15	750-1000	Austria, Belgium & Luxembourg, Bulgaria, Croatia, Czech Republic, Finland, Georgia, Hungary, Ireland, Netherlands, Portugal, Serbia & Montenegro, Switzerland, EUROCONTROL (incl. MUAC)	14
Medium-small	1	5-10	400-750	Bosnia & Herzegovina, Denmark, Slovakia	3
Small	1	<5	<400	Albania, Armenia, Cyprus, Estonia, Latvia, Lithuania, Malta, Moldova, North Macedonia, Slovenia	10

The next step was to calculate the CO_2 equivalent emissions that are generated at the point of electricity production. In carbon accounting, these are known as "Scope 2" emissions, which are "indirect greenhouse gas emissions associated with the purchase of electricity, steam, heat, or cooling. Although Scope 2 emissions physically occur at the facility where they are generated, they are accounted for in an organisation's inventory because they are a result of the organisation's energy use"[9]. We used the average EU emissions factor of 253g CO_2e/kWh published by the European Environment Agency to convert energy consumption into emissions, and applied it to all clusters, leading to the estimates shown in Figure 6.

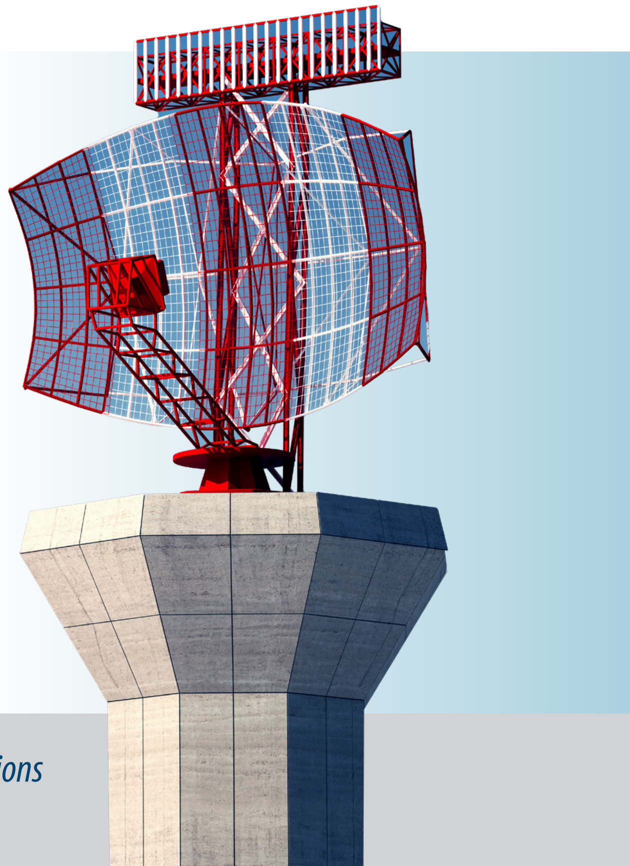
FIGURE 6: EUROPEAN ANSP CLUSTERING IN TERMS OF ESTIMATED AVERAGE ENERGY CONSUMPTION & CO_2e EMISSIONS

	Estimated average energy consumption (GWh)			Estimated average CO_2e emissions (t)	
CLUSTER	**No. of ANSPs**	**Annual per ANSP in cluster**	**Total**	**Annual per ANSP in cluster**	**Total**
Very large	2	110	220	27830	55660
Large	5	65	325	16445	82225
Medium-large	5	30	150	7590	37950
Medium	14	20	280	5060	70840
Medium-small	3	15	45	3795	11385
Small	10	12	120	3036	30360
TOTAL	**39**	**N/A**	**1140**	**N/A**	**288420**

Note*: "Very Large" clusters France with 5 ACCs and Turkey with 2. However, their estimated consumption and emissions are assumed to be similar, as their similar total staffing levels as per Figure 4 are assumed to require a similar amount of physical space.*

The estimated annual average consumption of 1,140GWh is roughly equivalent to 55% of Malta's annual energy consumption[10], meeting the needs of a population of 525,000[11] and a significant tourist industry.

Using the "carbon intensity" of each country's power generation based on data published annually by the European Environment Agency[12], we can further refine our figure of **288K** tonnes by calculating the "CO_2 equivalent" (CO_2e) emissions of the local electricity production sources (renewable, nuclear, oil, gas, coal). This yields a new figure of just over **311K tonnes CO_2e** – which, if it can be fully decarbonised, would represent a sizeable achievement that will contribute to greening European aviation.



"Fully decarbonising Europe's ATM ground infrastructure CO_2e emissions would significantly contribute to greening European aviation"

What are European ANSPs already doing to reduce their energy consumption?

Figure 7 lists some of the energy-reducing initiatives under way across Europe's ANSPs.

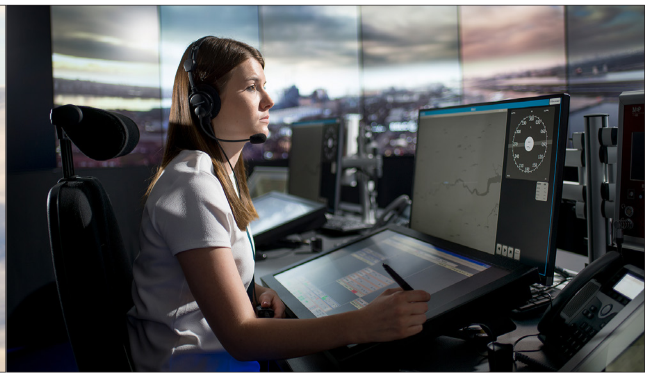
FIGURE 7: SELECTED ENERGY-SAVING INITIATIVES AT 6 EUROPEAN ANSPs

Austrocontrol	DSNA	ENAV
• 1.5GWh cut in electricity consumption over the past 5 years via measures such as deactivating its energy-intensive Buschberg radar station as a result of deploying a wide-area multilateration surveillance system[13] • Innovative reuse of decommissioned facilities, with its Freistadt VOR antenna platform repurposed as a mounting system for a photovoltaic array, and the electricity generated now used to power a communications antenna	• Innovative renewable energy solution planned for remote sites, producing electricity by hydrogen fuel cells, which are themselves powered by photovoltaic solar panels. This replaces the diesel generators typically used at such locations, reducing CO_2 emissions by 60% and lowering maintenance costs, while maintaining reliability and continuity. The Sarlat-la Canéda pilot was inaugurated on 14 September 2021[14] and aims to be the blueprint for similar installations at up to 20 SSR Mode S surveillance stations and 80 VHF (R/T) radio stations[15]	• Peripheral site trial at the Brancasi TBT radio centre to use hydrogen fuel cells in place of automatic backup generators to generate electricity. Rolling this out to all ENAV's peripheral sites will save an estimated 10 GWh and 5,000 tCO_2e annually • Photovoltaic electricity plants already installed at 5 facilities including ENAV HQ, with plans to roll them out to 6 control towers, 2 radio centres and its training centre by the end of 2022[16]

NATS	NAVIAIR	Skyguide
• 3.0GWh/month reduction in energy consumption over 13 years (2006: 8.0GWh; 2019: 5.0GWh), with NATS committed to reducing its CO_2 emissions to zero by 2050[17] • 10% reduction in electricity consumption 2020-2021 due to changing work patterns, and will continue to scale back the buildings in its portfolio and realise more energy savings from those it continues to occupy[18]	• 0.2GWh reduction in electricity consumption at its Copenhagen facilities, from 5.7GWh in 2017 to 5.5GWh in 2018. This drop was the result of replacing cooling machinery with new, more energy-efficient equipment, shutting down the local cooling systems and putting phase one of a new groundwater cooling system into service • Carbon footprint is measured to set CO_2 emissions reduction targets, with a reduction in energy consumption and increased use of renewables in its energy mix[19] • Overall energy consumption reduction target of approximately 500 MWh[20]	• 1.6GWh reduction in total energy consumption (2006: 14.5GWh; 2020: 12.9GWh) • 1.0GWh reduction in fuels for transport and heat (2006: 3.0GWh; 2020: 2.0GWh), with electricity consumption reducing from 11.5GWh to 11GWh over that period, and now 100% renewable[6] • Energy-efficient lighting & cooling machines • New energy-efficient data centre employing passive cooling[21]

In addition to energy-saving initiatives, some ANSPs have also cut back on their required infrastructure, deploying remote towers which allow aerodrome Air Traffic Control or Flight Information Services to be provided from a remote location. These are estimated to consume roughly 70% less electricity than a conventional aerodrome tower[7], also costing less to operate, while maintaining an equivalent level of operational safety.

Saab on-site camera tower, Sälen
© Saab



London City Digital Tower
© NATS

Moving to a zero carbon ATM infrastructure

The first step to take on the road to reducing an organisation's carbon footprint is to generate a baseline. EUROCONTROL and EASA have established a Working Group on ATM/ANS Environmental Transparency, one of whose tasks covers how ANSPs calculate their environmental footprints, allowing ANSPs to show improvements over time[22]. The results of that work should provide a clearer picture of ANSPs' energy consumption and greenhouse gas emissions.

The EUROCONTROL Network Manager's Operational Excellence Programme contains two work streams looking at how the CNS infrastructure should evolve, including its energy efficiency and carbon footprint. The data being gathered will be shared with the Environmental Transparency Working Group.

The estimates of 1,140GWh of energy consumption and 311KtCO_2e emissions published in this Think Paper only cover electricity consumption, but most ANSPs also use fossil fuels in their energy mix, something that the EUROCONTROL-EASA work should also factor into carbon footprinting. In addition, not all airports have ATC delivered by their national ANSPs: approach and terminal control is the one area of ANS provision that is open to competition and so there are several providers whose activities are not covered here. It is possible, therefore, that this Think Paper's initial estimates of total European ATM-related electricity consumption and CO_2 equivalent emissions are too low.

Switching to renewable energy supplies

The share of renewables in EU energy production has been increasing gradually, from 10% in 2005 to 20% in 2019, with a target of 32% in 2030[23]. Solar power alone generated almost 10% of EU energy needs in summer 2021[24]. The energy reduction measures discussed above are important steps by ANSPs on the path to achieving net zero greenhouse gas emissions.

Encouragingly, a number of ANSPs are further down that path, and have chosen as a matter of policy to decarbonise their electricity supplies completely, as the following examples show:

- skeyes, the Belgian ANSP, has used 100% green electricity since 2015[25], and has approved the installation of a solar farm at its main site adjacent to Brussels airport[26].

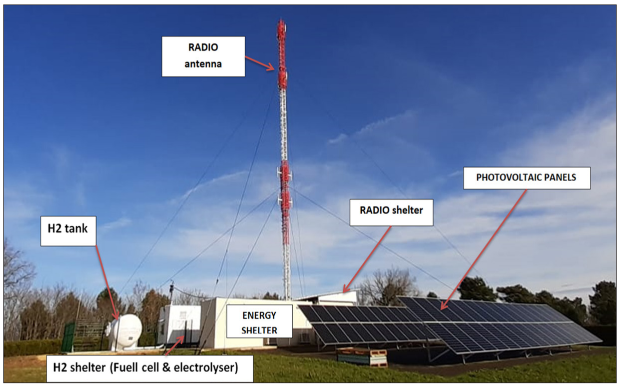
- DFS, as well as optimising its navigation and radar infrastructure to reduce energy consumption and emissions, is expanding its use of photovoltaic facilities[27].

"A number of ANSPs are further down the path of switching to renewable energy supplies"

- NATS purchased renewable electricity for over 96% of total electricity consumed in 2020-2021 (up from 93% in the previous reporting year). This is an example of a portfolio of activities that led to NATS being identified as a European Climate Leader by the Financial Times in 2021 for its environmental performance since 2014.[28]

- ENAV plans to switch to renewable sources to reduce its emissions from purchased energy by 96% by 2022 compared with 2019[29], and has initiated an energy efficiency upgrade plan to reduce its consumption by 30% by 2030[30].

- EUROCONTROL's Brussels facilities have been running on renewable energy for several years, and the roof on the new EUROCONTROL Network Operations Centre (currently under construction) will accommodate over 600 photovoltaic panels[31].



Sarlat-la Canéda radio antenna renewable energy emergency power supply (photo courtesy of DSNA).

If all ANSPs could follow these examples - by boosting their energy efficiency, installing renewable energy plants at their facilities, and switching to renewable energy supply contracts, and other green investment - **then ATM's ground infrastructure could potentially be progressively decarbonised over the next decade.** Moreover, as renewable energy becomes increasingly price-competitive, it is possible that **such a move could actually reduce ANSPs' operating expenditures in the medium term.**

Conclusions

The actions taken by European ANSPs to reduce their environmental impact by delivering more efficient airspace solutions are paralleled by a growing number of initiatives to reduce the carbon footprints generated by their energy consumption; but more can be done.

The estimates in this Think Paper are a first attempt to quantify the total potential emissions saving that greening Europe's ATM ground infrastructure could achieve over the course of the next decade, and are designed to stimulate decision-making in the years ahead.

MAIN FINDINGS

- European European ANSPs are estimated to consume **1,140GWh** of electricity annually, roughly equivalent to 55% of the annual energy consumption of Malta.

- Decarbonising this ground infrastructure by switching to and investing in renewable energy over the next decade could save **311K** tonnes of CO_2 equivalent emissions annually, summing up to over **6.2M** tonnes overall by 2050.

- Improving the energy efficiency of all ground infrastructure over the next 10 years will be both a challenge and a window of opportunity if successfully linked to investment cycles.

- Progress has already been made by some ANSPs towards switching to renewable energy contracts, or greening their facilities, which serve as best practice for their peers.

"Improving energy efficiency of ground infrastructure is both a challenge and a window of opportunity if linked to investment cycles"

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Greenpeace Energy – Energy Cooperative with a Mission

accurate as of January 2020

Our Business: More than Clean Energy

Greenpeace Energy is an energy cooperative operating throughout Germany that values responsible and sustainable action more than financial profits. We supply more than 173,000 customers, of which about 13,000 are business customers, with clean electricity and *pro*Windgas, an ecologically superior alternative to natural gas. The business is organised as a cooperative with more than 26,200 members whose contributions provide a solid equity capital base and, thus, stability. The fact that the members are not only the cooperative's owners but also its customers serves to prevent conflicts of interest: towards an ecologically oriented business policy, rather than profit maximisation.

Through our subsidiary Planet energy we build our own power plants. Thirteen wind farms and four photovoltaic plants totalling 90 MW are already in operation. Furthermore, we take a very active role in energy policy discussions and help to set the stage for the energy turnaround: We test new concepts, for example concerning electromobility, and we sponsor research projects to foster innovation and to smooth the way into a future of clean energy.

Our History: Greenpeace Campaign Evolves into Energy Supplier

The liberalisation of energy markets towards in the late 1990s opened up the possibility to supply customers with green electricity. The environmental protection organisation Greenpeace e.V. used the opportunity to develop criteria for high quality green electricity and, through the campaign "electricity switch", gathered supporters who demanded clean electricity. A public tender showed, however, that no supplier was able meet all criteria. Greenpeace e.V. in response took matters into their own hands and initiated in autumn 1999 the foundation of the cooperative Greenpeace Energy, an entity that is legally and financially independent of the environmental protection organisation. Greenpeace Energy started supplying customers with clean electricity according to the Greenpeace criteria on January 1st, 2000, and in 2001 founded the subsidiary Planet energy, which constructs green power plants.

Our Vision: Energy Turnaround now!

Our aim is the energy turnaround - energy supply from ecological sources, without coal and nuclear power. We fight for the environment and encourage as many people as possible to join us in shaping a future of clean energy. We combine political demands with solutions for the energy industry on behalf of our customers and cooperative owners.

Our Products: Join Us - Participate - Reshape the Energy Industry!

- **Green electricity**: The electricity we supply is exclusively sourced from renewable energy power plants. Since January 2015 we guarantee a share of 10% wind energy in our electricity mix. This minimum share will be increased in the coming years.
- ***pro*Windgas**: As of 2011, consumers can switch to our new gas tariff *pro*Windgas, the first of its kind in Germany. Its key technology is the conversion of green electricity - especially wind power - into hydrogen. Greenpeace Energy is thus pressing ahead with an innovative storage technology for renewable energy. In October 2011 we started supplying initially pure natural gas. In December 2014, we began to add renewable hydrogen. The gas tariff includes a

subsidy of 0.4 ct/kWh for the further development of windgas technologies. That’s how we invite our customers to help us shape the energy turnaround.

- **Green investment**: Our customers can contribute to the construction of wind farms and PV plants by purchasing participation rights. Such investment provides Planet energy with the necessary capital to expand its portfolio of power plants. At the same time, the investors profit from the economic success of the plants.
- **Cooperative shares**: The organisational form of Greenpeace Energy as a cooperative ensures its independence and transparency. All it takes is a share of €55 to join the cooperative and thereby to own one’s energy supplier.

U.S. Department of Transportation
Federal Aviation Administration
Regulatory Support Division, AFS-600

Date Effective: September 27, 2021

Subject: Learning Statement Reference Guide for Airman Knowledge Testing

Purpose: This reference guide contains the listings of Learning Statements and Learning Statement Codes for airman knowledge testing. It includes codes for pilots, remote pilots, instructors, flight engineers, dispatchers, navigators, pilot examiners, inspection authorization, parachute riggers, and aircraft mechanics.

General: The expression 'learning statement,' as used in airman testing, refers to measurable statements of knowledge that a student should be able to demonstrate following a defined element of training. In order that the individual learning statements may be read as complete sentences, they should be assumed to be preceded by the words: "Upon the successful completion of training the student should be able to . . . . "

In general, the learning statements are worded in such a way, the standard required to achieve them is self-evident. It should be noted that learning statements do not provide a ready-made ground training syllabus and should not be viewed as a substitute for thorough training course design.

When an applicant for an airman certificate or rating takes the applicable airman knowledge test required for that certificate/rating, the applicant will receive an Airman Knowledge Test Report. The test report will list the learning statement codes for questions that are answered incorrectly. The student should match the code with the learning statement code contained in this document to review areas of deficiency. An applicant's instructor is required to provide instruction on each of the areas of deficiency listed on the Airman Knowledge Test Report and to complete an endorsement of this instruction. The Airman Knowledge Test Report must be presented to the examiner conducting the practical test. During the oral portion of the practical test, the examiner is required to evaluate the noted areas of deficiency.

Electronic Access: The learning statement codes can be obtained from the Federal Aviation Administration (FAA) website at:
http://www.faa.gov/training_testing/testing/media/LearningStatementReferenceGuide.pdf

LEARNING STATEMENT CODES and LEARNING STATEMENTS
for Pilot, Remote Pilot, Instructor, Flight Engineer, Dispatcher, and Navigator Exams

PLT001	Calculate a course intercept
PLT002	Calculate aircraft performance – airspeed
PLT003	Calculate aircraft performance - center of gravity
PLT004	Calculate aircraft performance - climb / descent / maneuvering
PLT005	Calculate aircraft performance - density altitude
PLT006	Calculate aircraft performance – glide
PLT007	Calculate aircraft performance – IAS
PLT008	Calculate aircraft performance – landing
PLT009	Calculate aircraft performance - turbine temperatures (MGT, EGT, ITT, T4, etc) / torque / horsepower
PLT010	Calculate aircraft performance - STAB TRIM
PLT011	Calculate aircraft performance – takeoff
PLT012	Calculate aircraft performance - time/speed/distance/course/fuel/wind
PLT013	Calculate crosswind / headwind components
PLT014	Calculate distance / bearing to a station
PLT015	Calculate flight performance / planning – range / endurance
PLT016	Calculate fuel - dump time / weight / volume / quantity / consumption
PLT017	Calculate L/D ratio
PLT018	Calculate load factor / stall speed / velocity / angle of attack
PLT019	Calculate pressure altitude
PLT020	Calculate turbulent air penetration
PLT021	Calculate weight and balance
PLT022	Define Aeronautical Decision Making (ADM)
PLT023	Define altitude - absolute / true / indicated / density / pressure
PLT024	Define atmospheric adiabatic process
PLT025	Define Bernoulli`s principle
PLT026	Define ceiling
PLT027	Define coning
PLT028	Define crewmember
PLT029	Define critical phase of flight
PLT030	Define false lift
PLT031	Define isobars / associated winds
PLT032	Define MACH speed regimes
PLT033	Define MEA / MOCA / MRA
PLT034	Define stopway / clearway
PLT035	Define Vne / Vno
PLT036	Interpret a MACH meter reading
PLT037	Interpret a Radar Weather Report / National Convective Weather Forecast
PLT038	Interpret aircraft Power Schedule Chart
PLT039	Interpret airport landing indicator
PLT040	Interpret airspace classes - charts / diagrams
PLT041	Interpret altimeter - readings / settings
PLT042	Interpret Constant Pressure charts / Isotachs Chart
PLT043	Interpret Analysis Heights / Temperature Chart

LEARNING STATEMENT CODES and LEARNING STATEMENTS
for Pilot, Instructor, Flight Engineer, Dispatcher, and Navigator Exams

PLT044 Interpret ATC communications / instructions / terminology
PLT045 Interpret Descent Performance Chart
PLT046 Interpret drag ratio from charts
PLT047 Interpret/Program Flight Director/FMS/Automation - modes / operation / indications / errors
PLT048 Interpret Hovering Ceiling Chart
PLT049 Interpret ILS - charts / RMI / CDI / indications
PLT050 Interpret information on a Brake Energy Limit Chart
PLT051 Interpret information on a Convective Outlook
PLT052 Interpret information on a Departure Procedure Chart
PLT053 Interpret information on a Flight Plan
PLT054 Interpret information on a Glider Performance Graph
PLT055 Interpret information on a High Altitude Chart
PLT056 Interpret information on a Horizontal Situation Indicator (HSI)
PLT057 Interpret information on a Hot Air Balloon Performance Graph
PLT058 Interpret information on a Low Altitude Chart
PLT059 Interpret information on a METAR / SPECI report
PLT060 Interpret information on a Performance Curve Chart
PLT061 Interpret information on a PIREP
PLT062 Interpret information on a Pseudo-Adiabatic Chart / K Index / Lifted Index
~~PLT063~~ ~~Interpret information on a Radar Summary Chart~~ (DELETED)
PLT064 Interpret information on a Sectional Chart
PLT065 Interpret information on a Service Ceiling Engine Inoperative Chart
PLT066 Interpret information on a Convective Outlook Chart
PLT067 Interpret information on a SIGMET
PLT068 Interpret information on a Significant Weather Prognostic Chart
PLT069 Interpret information on a Slush/Standing Water Takeoff Chart
PLT070 Interpret information on a Stability Chart
PLT071 Interpret information on a Surface Analysis Chart
PLT072 Interpret information on a Terminal Aerodrome Forecast (TAF)
PLT073 Interpret information on a Tower Enroute Control (TEC)
PLT074 Interpret information on a Velocity/Load Factor Chart
~~PLT075~~ ~~Interpret information on a Weather Depiction Chart~~ (DELETED 6/12/2017)
PLT076 Interpret information on a Winds and Temperatures Aloft Forecast (FB)
PLT077 Interpret information on an Airport Diagram
PLT078 Interpret information in a Chart Supplements U.S.
PLT079 Interpret information on an Airways Chart
PLT080 Interpret information on an Arrival Chart
~~PLT081~~ ~~Interpret information on an Aviation Area Forecast (FA)~~ (DELETED 6/12/2017)
PLT082 Interpret information on an IFR Alternate Airport Minimums Chart
PLT083 Interpret information on an Instrument Approach Procedures (IAP)
PLT084 Interpret information on an Observed Winds Aloft Chart
PLT085 Interpret information on Takeoff Obstacle / Field / Climb Limit Charts
PLT086 Interpret readings on a Turn and Slip Indicator

LEARNING STATEMENT CODES and LEARNING STATEMENTS
for Pilot, Instructor, Flight Engineer, Dispatcher, and Navigator Exams

PLT087	Interpret readings on an Aircraft Course and DME Indicator
PLT088	Interpret speed indicator readings
PLT089	Interpret Takeoff Speeds Chart
PLT090	Interpret VOR - charts / indications / CDI / NAV
PLT091	Interpret VOR / CDI - illustrations / indications / procedures
PLT092	Interpret weight and balance - diagram
PLT093	Recall administration of medical oxygen
PLT094	Recall aerodynamics - airfoil design / pressure distribution / effects of altitude
PLT095	Recall aerodynamics - longitudinal axis / lateral axis
PLT096	Recall aeromedical factors - effects of altitude
PLT097	Recall aeromedical factors - effects of carbon monoxide poisoning
PLT098	Recall aeromedical factors - fitness for flight
PLT099	Recall aeromedical factors - scanning procedures
PLT100	Recall aeronautical charts - IFR En Route Low Altitude
PLT101	Recall aeronautical charts - pilotage
PLT102	Recall aeronautical charts - terminal procedures
PLT103	Recall Aeronautical Decision Making (ADM) - hazardous attitudes
PLT104	Recall Aeronautical Decision Making (ADM) - human factors / CRM
PLT105	Recall airborne radar / thunderstorm detection equipment - use / limitations
PLT106	Recall aircraft air-cycle machine
PLT107	Recall aircraft alternator / generator system
PLT108	Recall aircraft anti-icing / deicing - methods / fluids
PLT109	Recall aircraft batteries - capacity / charging / types / storage / rating / precautions
PLT110	Recall aircraft brake system
PLT111	Recall aircraft circuitry - series / parallel
PLT112	Recall aircraft controls - proper use / techniques
PLT113	Recall aircraft design - categories / limitation factors
PLT114	Recall aircraft design - construction / function
PLT115	Recall aircraft engine - detonation/backfiring/after firing, cause/characteristics
PLT116	Recall aircraft general knowledge / publications / AIM / navigational aids
PLT117	Recall aircraft heated windshields
PLT118	Recall aircraft instruments - gyroscopic
PLT119	Recall aircraft lighting - anti-collision / landing / navigation
PLT120	Recall aircraft limitations - turbulent air penetration
PLT121	Recall aircraft loading - computations
PLT122	Recall aircraft operations - checklist usage
PLT123	Recall aircraft performance - airspeed
PLT124	Recall aircraft performance - atmospheric effects
PLT125	Recall aircraft performance - climb / descent
PLT126	Recall aircraft performance - cold weather operations
PLT127	Recall aircraft performance - density altitude
PLT128	Recall aircraft performance - effects of icing
PLT129	Recall aircraft performance - effects of runway slope / slope landing

LEARNING STATEMENT CODES and LEARNING STATEMENTS
for Pilot, Instructor, Flight Engineer, Dispatcher, and Navigator Exams

PLT130	Recall aircraft performance - fuel
PLT131	Recall aircraft performance - ground effect
PLT132	Recall aircraft performance - instrument markings / airspeed / definitions / indications
PLT133	Recall aircraft performance - normal climb / descent rates
PLT134	Recall aircraft performance - takeoff
PLT135	Recall aircraft pressurization - system / operation
PLT136	Recall aircraft systems - anti-icing / deicing
PLT137	Recall aircraft systems - environmental control
PLT138	Recall aircraft landing gear/tires - types / characteristics
PLT139	Recall aircraft warning systems - stall / fire / retractable gear / terrain awareness
PLT140	Recall airport operations - LAHSO
PLT141	Recall airport operations - markings / signs / lighting
PLT142	Recall airport operations - noise avoidance routes
PLT143	Recall airport operations - rescue / fire fighting vehicles and types of agents
PLT144	Recall airport operations - runway conditions
PLT145	Recall airport operations - runway lighting
PLT146	Recall airport operations - traffic pattern procedures / communication procedures
PLT147	Recall airport operations - visual glide path indicators
PLT148	Recall airport operations lighting - MALS / ALSF / RCLS / TDZL
PLT149	Recall airport preflight / taxi operations - procedures
PLT150	Recall airport traffic patterns - entry procedures
PLT151	Recall airship - buoyancy
PLT152	Recall airship - flight characteristics / controllability
PLT153	Recall airship - flight operations
PLT154	Recall airship - ground weight-off / static / trim condition
PLT155	Recall airship - maintaining pressure
PLT156	Recall airship - maximum headway / flight at equilibrium
PLT157	Recall airship - pressure height / dampers / position
PLT158	Recall airship - pressure height / manometers
PLT159	Recall airship - pressure height / super heat / valving gas
PLT160	Recall airship - stability / control / positive superheat
PLT161	Recall airspace classes - limits / requirements / restrictions / airspeeds / equipment
PLT162	Recall airspace requirements - operations
PLT163	Recall airspace requirements - visibility / cloud clearance
PLT164	Recall airspeed - effects during a turn
PLT165	Recall altimeter - effect of temperature changes
PLT166	Recall altimeter - settings / setting procedures
PLT167	Recall altimeters - characteristics / accuracy
PLT168	Recall angle of attack - characteristics / forces / principles
PLT169	Recall antitorque system - components / functions
PLT170	Recall approach / landing / taxiing techniques

LEARNING STATEMENT CODES and LEARNING STATEMENTS
for Pilot, Instructor, Flight Engineer, Dispatcher, and Navigator Exams

PLT171 Recall ATC - reporting
PLT172 Recall ATC - system / services
PLT173 Recall atmospheric conditions - measurements / pressure / stability
PLT174 Recall autopilot / yaw damper - components / operating principles / characteristics / failure modes
PLT175 Recall autorotation
PLT176 Recall balance tab - purpose / operation
PLT177 Recall balloon - flight operations
PLT178 Recall balloon - flight operations / gas
PLT179 Recall balloon - ground weigh-off / static equilibrium / load
PLT180 Recall balloon gas/hot air - lift / false lift / characteristics
PLT181 Recall balloon - hot air / physics
PLT182 Recall balloon - inspecting the fabric
PLT183 Recall balloon flight operations - ascent / descent
PLT184 Recall balloon flight operations - launch / landing
PLT185 Recall basic instrument flying - fundamental skills
PLT186 Recall basic instrument flying - pitch instruments
PLT187 Recall basic instrument flying - turn coordinator / turn and slip indicator
PLT188 Recall cabin atmosphere control
PLT189 Recall carburetor - effects of carburetor heat / heat control
PLT190 Recall carburetor ice - factors affecting / causing
PLT191 Recall carburetors - types / components / operating principles / characteristics
PLT192 Recall clouds - types / formation / resulting weather
PLT193 Recall cockpit voice recorder (CVR) - operating principles / characteristics / testing
PLT194 Recall collision avoidance - scanning techniques
PLT195 Recall collision avoidance - TCAS
PLT196 Recall communications - ATIS broadcasts
PLT197 Recall Coriolis effect
PLT198 Recall course / heading - effects of wind
PLT199 Recall cyclic control pressure - characteristics
PLT200 Recall dead reckoning - calculations / charts
PLT201 Recall departure procedures - ODP / SID
PLT202 Recall DME - characteristics / accuracy / indications / Arc
PLT203 Recall earth`s atmosphere - layers / characteristics / solar energy
PLT204 Recall effective communication - basic elements
PLT205 Recall effects of alcohol on the body
PLT206 Recall effects of temperature - density altitude / icing
PLT207 Recall electrical system - components / operating principles / characteristics / static bonding and shielding
PLT208 Recall emergency conditions / procedures
~~PLT209~~ ~~Recall engine pressure ratio – EPR~~ (DELETED)
PLT210 Recall engine shutdown - normal / abnormal / emergency / precautions
PLT211 Recall evaluation testing characteristics

PLT212	Recall fire extinguishing systems - components / operating principles / characteristics
PLT213	Recall flight characteristics - longitudinal stability / instability
PLT214	Recall flight characteristics - structural / wing design
PLT215	Recall flight instruments - magnetic compass
PLT216	Recall flight instruments - total energy compensators
PLT217	Recall flight maneuvers - quick stop
PLT218	Recall flight operations - common student errors
PLT219	Recall flight operations - maneuvers
PLT220	Recall flight operations - night and high altitude operations
PLT221	Recall flight operations - takeoff / landing maneuvers
PLT222	Recall flight operations - takeoff procedures
PLT223	Recall flight operations multiengine - engine inoperative procedures
PLT224	Recall flight plan - IFR
PLT225	Recall flight plan - requirements
PLT226	Recall fog - types / formation / resulting weather
PLT227	Recall FOI techniques - integrated flight instruction
PLT228	Recall FOI techniques - lesson plans
PLT229	Recall FOI techniques - professionalism
PLT230	Recall FOI techniques - responsibilities
PLT231	Recall FOI techniques / human behavior - anxiety / fear / stress
PLT232	Recall FOI techniques / human behavior - dangerous tendencies
PLT233	Recall FOI techniques / human behavior - defense mechanisms
PLT234	Recall forces acting on aircraft - 3 axis intersect
PLT235	Recall forces acting on aircraft - aerodynamics
PLT236	Recall forces acting on aircraft - airfoil / center of pressure / mean camber line
PLT237	Recall forces acting on aircraft - airspeed / air density / lift / drag
PLT238	Recall forces acting on aircraft - aspect ratio
PLT239	Recall forces acting on aircraft - buoyancy / drag / gravity / thrust
PLT240	Recall forces acting on aircraft - CG / flight characteristics
PLT241	Recall forces acting on aircraft - drag / gravity / thrust / lift
PLT242	Recall forces acting on aircraft - lift / drag / thrust / weight / stall / limitations
PLT243	Recall forces acting on aircraft - propeller / torque
PLT244	Recall forces acting on aircraft - stability / controllability
PLT245	Recall forces acting on aircraft - stalls / spins
PLT246	Recall forces acting on aircraft - steady state climb / flight
PLT247	Recall forces acting on aircraft - thrust / drag / weight / lift
PLT248	Recall forces acting on aircraft - turns
PLT249	Recall fuel - air mixture
PLT250	Recall fuel - types / characteristics / contamination / fueling / defueling / precautions
PLT251	Recall fuel characteristics / contaminants / additives
PLT252	Recall fuel dump system - components / methods

PLT253	Recall fuel system - components / operating principles / characteristics / leaks
PLT254	Recall fuel tank - components / operating principles / characteristics
PLT255	Recall fueling procedures - safety / grounding / calculating volume
PLT256	Recall glider performance - effect of loading
PLT257	Recall glider performance - speed / distance / ballast / lift / drag
PLT258	Recall ground reference maneuvers - ground track diagram
PLT259	Recall ground resonance - conditions to occur
PLT260	Recall gyroplane - aerodynamics / rotor systems
PLT261	Recall hail - characteristics / hazards
PLT262	Recall helicopter hazards - dynamic rollover / Low G / LTE
PLT263	Recall hazardous weather - fog / icing / turbulence / visibility restriction
PLT264	Recall helicopter approach - settling with power
PLT265	Recall helicopter takeoff / landing - ground resonance action required
PLT266	Recall high lift devices - characteristics / functions
PLT267	Recall hot air balloon – weigh-off procedure
PLT268	Recall hovering - aircraft performance / tendencies
PLT269	Recall human behavior - defense mechanism
PLT270	Recall human behavior – personality / human needs / adult learning
PLT271	Recall human factors (ADM) - judgment
PLT272	Recall human factors - stress management
PLT273	Recall hydraulic systems - components / operating principles / characteristics
PLT274	Recall icing - formation / characteristics
PLT275	Recall ILS - indications / HSI
PLT276	Recall ILS - indications / OBS / CDI
PLT277	Recall ILS - marker beacon / indicator lights / codes
PLT278	Recall indicating systems - airspeed / angle of attack / attitude / heading / manifold pressure / synchro / EGT
PLT279	Recall Inertial/Doppler Navigation System principles / regulations / requirements / limitations
PLT280	Recall inflight illusions - causes / sources
PLT281	Recall information in a Chart Supplements U.S.
PLT282	Recall information in the certificate holder`s manual
PLT283	Recall information on a Constant Pressure Analysis Chart
PLT284	Recall information on a Forecast Winds and Temperatures Aloft (FB)
PLT285	Recall information on a Height Velocity Diagram
PLT286	Recall information on a Significant Weather Prognostic Chart
PLT287	Recall information on a Surface Analysis Chart
PLT288	Recall information on a Terminal Aerodrome Forecast (TAF)
PLT289	Recall information on a Weather Depiction Chart
PLT290	Recall information on AIRMETS / SIGMETS
~~PLT291~~	~~Recall information on an Aviation Area Forecast (FA)~~ (DELETED 6/12/2017)
PLT292	Recall information on an Instrument Approach Procedures (IAP)
PLT293	Recall information on an Instrument Departure Procedure Chart
PLT294	Recall information on Inflight Aviation Weather Advisories

PLT295	Recall instructor techniques - obstacles / planning / activities / outcome
PLT296	Recall instrument procedures - holding / circling
PLT297	Recall instrument procedures - unusual attitude / unusual attitude recovery
PLT298	Recall instrument procedures - VFR on top
PLT300	Recall instrument/navigation system checks/inspections - limits / tuning / identifying / logging
PLT301	Recall inversion layer - characteristics
PLT302	Recall jet stream - types / characteristics
PLT303	Recall L/D ratio
PLT304	Recall launch / aero-tow procedures
PLT305	Recall leading edge devices - types / effect / purpose / operation
PLT306	Recall learning process – theory / definition / levels, style, transfer of learning / incidental learning / acquiring skill
PLT307	Recall learning process - memory / fact / recall
PLT308	Recall learning process - laws of learning elements
PLT309	Recall load factor - angle of bank
PLT310	Recall load factor - characteristics
PLT311	Recall load factor - effect of airspeed
PLT312	Recall load factor - maneuvering / stall speed
PLT313	Recall loading – limitations / terminology
PLT314	Recall longitudinal axis - aerodynamics / center of gravity / direction of motion
PLT315	Recall Machmeter - principles / functions
PLT316	Recall meteorology - severe weather watch (WW)
PLT317	Recall microburst - characteristics / hazards
PLT318	Recall minimum fuel advisory
PLT319	Recall navigation – celestial / navigation chart / characteristics
PLT320	Recall navigation - true north / magnetic north
PLT321	Recall navigation - types of landing systems
PLT322	Recall navigation - VOR / NAV system
PLT323	Recall NOTAMS - classes / information / distribution
PLT324	Recall oil system - types / components / functions / oil specifications
PLT325	Recall operations manual - transportation of prisoner
PLT326	Recall oxygen system - components / operating principles / characteristics
PLT327	Recall oxygen system - install / inspect / repair / service / precautions / leaks
PLT328	Recall performance planning - aircraft loading
PLT329	Recall physiological factors - cabin pressure
PLT330	Recall physiological factors - cause / effects of hypoxia
PLT331	Recall physiological factors - effects of scuba diving / smoking
PLT332	Recall physiological factors – hyperventilation / stress / fatigue
PLT333	Recall physiological factors - night vision
PLT334	Recall physiological factors - spatial disorientation
PLT335	Recall pilotage - calculations
PLT336	Recall pitch control - collective / cyclic

PLT337	Recall pitot-static system - components / operating principles / characteristics
PLT338	Recall pneumatic system - operation
PLT340	Recall positive exchange of flight controls
PLT341	Recall power settling - characteristics
PLT342	Recall powerplant - controlling engine temperature
PLT343	Recall powerplant - operating principles / operational characteristics / inspecting
PLT344	Recall precipitation - types / characteristics
PLT345	Recall pressure altitude
PLT346	Recall primary / secondary flight controls - types / purpose / functionality / operation
PLT347	Recall principles of flight - critical engine
PLT348	Recall principles of flight - turns
PLT349	Recall procedures for confined areas
PLT350	Recall propeller operations - constant / variable speed
PLT351	Recall propeller system - types / components / operating principles / characteristics
PLT352	Recall purpose / operation of a stabilizer
PLT353	Recall Radar Summary Chart
PLT354	Recall radio - GPS / RNAV / RAIM
PLT355	Recall radio - HSI
PLT356	Recall radio - ILS / compass locator
PLT357	Recall radio - ILS
PLT358	Recall radio - LOC / ILS
~~PLT359~~	~~Recall radio – LORAN~~ (DELETED)
~~PLT360~~	~~Recall radio - Microwave Landing System~~ (DELETED)
~~PLT361~~	~~Recall radio - SDF / ILS~~ (DELETED)
~~PLT362~~	~~Recall radio - VHF / Direction Finding~~ (DELETED)
PLT363	Recall radio - VOR / VOT
PLT364	Recall radio system - license requirements / frequencies
PLT365	Recall reciprocating engine - components / operating principles / characteristics
PLT366	Recall regulations - accident / incident reporting and preserving wreckage
PLT367	Recall regulations - additional equipment/operating requirements large transport aircraft
PLT368	Recall regulations - admission to flight deck
PLT369	Recall regulations - aerobatic flight requirements
PLT370	Recall regulations - Air Traffic Control authorization / clearances
PLT371	Recall regulations - Aircraft Category / Class
PLT372	Recall regulations - aircraft inspection / records / expiration
PLT373	Recall regulations - aircraft operating limitations
PLT374	Recall regulations - aircraft owner / operator responsibilities
PLT375	Recall regulations - aircraft return to service
PLT376	Recall regulations - airspace, other, special use / TFRS
PLT377	Recall regulations - airworthiness certificates / requirements / responsibilities

PLT378	Recall regulations - Airworthiness Directives
PLT379	Recall regulations - alternate airport requirements
PLT380	Recall regulations - alternate airport weather minima
PLT381	Recall regulations - altimeter settings
PLT382	Recall regulations - approach minima
PLT383	Recall regulations - basic flight rules
PLT384	Recall regulations - briefing of passengers
PLT385	Recall regulations - cargo in passenger compartment
PLT386	Recall regulations - certificate issuance / renewal
PLT387	Recall regulations - change of address
PLT388	Recall regulations - cockpit voice / flight data recorder(s)
PLT389	Recall regulations - commercial operation requirements / conditions / OpSpecs
PLT390	Recall regulations - communications enroute
PLT391	Recall regulations - communications failure
PLT392	Recall regulations - compliance with local regulations
PLT393	Recall regulations - controlled / restricted airspace - requirements
PLT394	Recall regulations - declaration of an emergency
PLT395	Recall regulations - definitions
PLT396	Recall regulations - departure alternate airport
PLT397	Recall regulations - destination airport visibility
PLT398	Recall regulations - dispatch
PLT399	Recall regulations - display / inspection of licenses and certificates
PLT400	Recall regulations - documents to be carried on aircraft during flight
PLT401	Recall regulations - dropping / aerial application / towing restrictions
PLT402	Recall regulations - ELT requirements
PLT403	Recall regulations - emergency deviation from regulations
PLT404	Recall regulations - emergency equipment
PLT405	Recall regulations - equipment / instrument / certificate requirements
PLT406	Recall regulations - equipment failure
PLT407	Recall regulations - experience / training requirements
PLT408	Recall regulations - fire extinguisher requirements
PLT409	Recall regulations - flight / duty time
PLT410	Recall regulations - flight engineer qualifications / privileges / responsibilities
PLT411	Recall regulations - flight instructor limitations / qualifications
PLT412	Recall regulations - flight release
PLT413	Recall regulations - fuel requirements
PLT414	Recall regulations - general right-of-way rules
PLT415	Recall regulations - IFR flying
PLT416	Recall regulations - immediate notification
PLT417	Recall regulations - individual flotation devices
PLT418	Recall regulations - instructor demonstrations / authorizations
PLT419	Recall regulations - instructor requirements / responsibilities
PLT420	Recall regulations - instrument approach procedures

LEARNING STATEMENT CODES and LEARNING STATEMENTS for Pilot, Instructor, Flight Engineer, Dispatcher, and Navigator Exams

PLT421	Recall regulations - instrument flight rules
PLT422	Recall regulations - intermediate airport authorizations
PLT423	Recall regulations - knowledge and skill test checks
PLT424	Recall regulations - limits on autopilot usage
PLT425	Recall regulations - maintenance reports / records / entries
PLT426	Recall regulations - maintenance requirements
PLT427	Recall regulations - medical certificate requirements / validity
PLT428	Recall regulations - minimum equipment list
PLT429	Recall regulations - minimum flight / navigation instruments
PLT430	Recall regulations - minimum safe / flight altitude
PLT431	Recall regulations - operating near other aircraft
PLT432	Recall regulations - operational control functions
PLT433	Recall regulations - operational flight plan requirements
PLT434	Recall regulations - operational procedures for a controlled airport
PLT435	Recall regulations - operational procedures for an uncontrolled airport
PLT436	Recall regulations - operations manual
PLT437	Recall regulations - overwater operations
PLT438	Recall regulations - oxygen requirements
PLT439	Recall regulations - persons authorized to perform maintenance
PLT440	Recall regulations - Pilot / Crew duties and responsibilities
PLT441	Recall regulations - pilot briefing
PLT442	Recall regulations - pilot currency requirements
PLT443	Recall regulations - pilot qualifications / privileges / responsibilities / crew complement
PLT444	Recall regulations - pilot-in-command authority / responsibility
PLT445	Recall regulations - preflight requirements
PLT446	Recall regulations - preventative maintenance
PLT447	Recall regulations - privileges / limitations of medical certificates
PLT448	Recall regulations - privileges / limitations of pilot certificates
PLT449	Recall regulations - proficiency check requirements
PLT450	Recall regulations - qualifications / duty time
PLT451	Recall regulations - ratings issued / experience requirements / limitations
PLT452	Recall regulations - re-dispatch
PLT453	Recall regulations - records retention for domestic / flag air carriers
PLT454	Recall regulations - required aircraft / equipment inspections
PLT455	Recall regulations - requirements of a flight plan release
PLT456	Recall regulations - runway requirements
PLT457	Recall regulations - student pilot endorsements / other endorsements
PLT458	Recall regulations - submission / revision of Policy and Procedure Manuals
PLT459	Recall regulations - takeoff procedures / minimums
PLT460	Recall regulations - training programs
PLT461	Recall regulations - use of aircraft lights

LEARNING STATEMENT CODES and LEARNING STATEMENTS for Pilot, Instructor, Flight Engineer, Dispatcher, and Navigator Exams

PLT462	Recall regulations - use of microphone / megaphone / interphone / public address system
PLT463	Recall regulations alcohol or drugs
PLT464	Recall regulations - use of safety belts / harnesses (crew member)
PLT465	Recall regulations - use of seats / safety belts / harnesses (passenger)
PLT466	Recall regulations - V speeds
PLT467	Recall regulations - visual flight rules and limitations
PLT468	Recall regulations - Visual Meteorological Conditions (VMC)
PLT469	Recall regulations - weather radar
PLT470	Recall rotor system - types / components / operating principles / characteristics
PLT471	Recall rotorcraft transmission - components / operating principles / characteristics
PLT472	Recall rotorcraft vibration - characteristics / sources
PLT473	Recall secondary flight controls - types / purpose / functionality
PLT474	Recall soaring - normal procedures
PLT475	Recall squall lines - formation / characteristics / resulting weather
PLT476	Recall stabilizer - purpose / operation
PLT477	Recall stalls - characteristics / factors / recovery / precautions
PLT478	Recall starter / ignition system - types / components / operating principles / characteristics
PLT479	Recall starter system - starting procedures
PLT480	Recall static/dynamic stability/instability - characteristics
PLT481	Recall student evaluation - learning process
PLT482	Recall student evaluation - written tests / oral quiz / critiques
PLT483	Recall supercharger - characteristics / operation
PLT484	Recall symbols - chart / navigation
PLT485	Recall taxiing / crosswind / techniques
PLT486	Recall taxiing / takeoff - techniques / procedures
PLT487	Recall teaching methods - demonstration / performance
PLT488	Recall teaching methods - group / guided discussion / lecture
PLT489	Recall teaching methods - known to unknown
PLT490	Recall teaching methods - motivation / student feelings of insecurity
PLT491	Recall teaching methods – process / organize material / course of training
PLT492	Recall temperature - effects on weather formations
PLT493	Recall the dynamics of frost / ice / snow formation on an aircraft
PLT494	Recall thermals - types / characteristics / formation / locating / maneuvering / corrective actions
PLT495	Recall thunderstorms - types / characteristics / formation / hazards / precipitation static
PLT496	Recall towrope - strength / safety links / positioning
PLT497	Recall transponder - codes / operations / usage
PLT498	Recall Transportation Security Regulations
PLT499	Recall turbine engines - components / operational characteristics / associated instruments
PLT500	Recall turboprop engines - components / operational characteristics

LEARNING STATEMENT CODES and LEARNING STATEMENTS
for Pilot, Instructor, Flight Engineer, Dispatcher, and Navigator Exams

PLT501	Recall turbulence - types / characteristics / reporting / corrective actions
PLT502	Recall universal signals - hand / light / visual
PLT503	Recall use of narcotics / drugs / intoxicating liquor
PLT504	Recall use of training aids - types / function / purpose
PLT505	Recall use of training aids - usefulness / simplicity / compatibility
PLT506	Recall V speeds - maneuvering / flap extended / gear extended / V1, V2, r, ne, mo, mc, mg, etc.
PLT507	Recall VOR - indications / VOR / VOT / CDI
PLT508	Recall VOR/altimeter/transponder checks - identification / tuning / identifying / logging
PLT509	Recall wake turbulence - characteristics / avoidance techniques
PLT510	Recall weather - causes / formation
PLT511	Recall weather associated with frontal activity / air masses
PLT512	Recall weather conditions - temperature / moisture / dewpoint
PLT513	Recall weather information - FAA Avcams
PLT514	Recall weather reporting systems - briefings / forecasts / reports / AWOS / ASOS
PLT515	Recall weather services - TIBS / TPC / WFO / HIWAS
PLT516	Recall winds - types / characteristics
PLT517	Recall winds associated with high / low-pressure systems
PLT518	Recall windshear - characteristics / hazards / power management
PLT519	Recall wing spoilers - purpose / operation
PLT520	Calculate density altitude
PLT521	Recall helicopter takeoff / landing – slope operations
PLT522	Recall helicopter – Pinnacle / Ridgeline operations
PLT523	Recall vortex generators – purpose / effects / aerodynamics
PLT524	Interpret / Program information on an avionics display
PLT525	Interpret table – oxygen / fuel / oil / accumulator / fire extinguisher
PLT526	Recall near midair collision report
PLT527	Recall BASIC VFR – weather minimums
PLT528	Recall regulations – small UAS operations / weight limitations
PLT529	Recall physiological factors – prescription and over-the-counter drugs
PLT530	Recall regulations – small UAS aircraft registration / display of registration
PLT531	Recall regulations – operation of multiple sUAs
PLT532	Recall operating limitations – small UAS aircraft visibility / distance from clouds
PLT533	Recall regulations – small UAS operation over humans
PLT534	Recall regulations – small UAS operational control / condition for safe operation / VLOS / frequency interference
PLT535	Recall regulations – hazardous operations
PLT536	Recall physiological factors – dehydration / heat stroke
PLT537	Recall regulations – sUAS waivers
PLT538	Recall regulations – BasicMed
PLT539	Recall information in a POH/AFM
PLT540	Recall airport operations – rotating beacon
PLT541	Recall information on an Aircraft Registration Certificate

PLT542	Recall airport operations - radio failure
PLT543	Recall Regulations – RVSM
PLT544	Recall Voluntary Reporting Programs – ASAP / NASA
PLT545	Recall teaching methods – problem-based
PLT546	Recall Authentic Assessment
PLT547	Recall teaching risk management – identification / assessment / mitigation
PLT548	Recall teaching risk management – FRATs
PLT549	Recall teaching risk management – introducing risk management
PLT550	Recall risk management – identification / assessment / mitigation
PLT551	Recall risk management – FRATs
PLT552	Recall collision avoidance – TIS

LEARNING STATEMENT CODES and LEARNING STATEMENTS for Parachute Rigger Exams

RIG001	Recall canopy - characteristics / design / inspection / malfunction / repair
RIG002	Recall canopy - exit weight / deployment and flight characteristics
RIG003	Recall canopy - folding / packing / stowage / layout
RIG004	Recall canopy - packing / stowage / layout
RIG005	Recall canopy deployment - devices / sequence / malfunction
RIG006	Recall certification - requirements / privileges / currency / limitations
RIG007	Recall container - design / repair / packing
RIG008	Recall correct rigging procedures
RIG009	Recall fabric - inspection / repair / design / characteristics
RIG010	Recall forces acting on a parachute
RIG011	Recall harness - assembly / adjustment
RIG012	Recall knots - identification / design / repair
RIG013	Recall line replacement / repair - procedures / techniques
RIG014	Recall maintenance fundamentals - cleaning / storage
RIG015	Recall material - threads / defects
RIG016	Recall material - webbing / hook and pile / warp threads
RIG017	Recall packing - airing / drying
RIG018	Recall packing fundamentals - handling / cleaning / storage
RIG019	Recall parachute construction - components
RIG020	Recall parachute performance
RIG021	Recall parachute repair - stitching / seams
RIG022	Recall patching - procedures / techniques
RIG023	Recall ram-air canopy - deployment devices
RIG024	Recall ram-air canopy - design / container / harness
RIG025	Recall ram-air canopy - inspection / assembly / malfunction / repair
RIG026	Recall regulation - Airworthiness Directive
RIG027	Recall regulations - facilities / equipment
RIG028	Recall regulations - foreign parachutists / equipment
RIG029	Recall regulations - inspecting / closing / finishing / sealing parachutes
RIG030	Recall regulations - major / minor repairs / alterations
RIG031	Recall regulations - performance standards
RIG032	Recall regulations - records
RIG033	Recall regulatory requirements - rules & regulations
RIG034	Recall regulatory specifics - rules & regulations
RIG035	Recall ripcord - inspection / repair / replacement / assembly / design / functions
RIG036	Recall sewing - repair / maintenance
RIG037	Recall sewing machine - attachments / needles / thread
RIG038	Recall sewing machine - techniques / adjusting / troubleshooting
RIG039	Recall sewing machine - types / components / functions
RIG040	Recall stitching / seams - types / design / repair
RIG041	Recall suspension / steering lines - inspection / repair / packing / malfunction / design
RIG042	Recall tools
RIG043	Recall TSO requirements
RIG044	Recall types of cuts - shearing / searing / cutting

LEARNING STATEMENT CODES and LEARNING STATEMENTS for Inspection Authorization

IAR001	Calculate alteration specification
IAR002	Calculate center of gravity
IAR003	Calculate electrical load
IAR004	Calculate proof loading
IAR005	Calculate repair specific
IAR006	Calculate sheet metal repair
IAR007	Calculate temperature conversion
IAR008	Calculate weight and balance - adjust weight / fuel
IAR009	Determine alteration parameters
IAR010	Determine alteration requirements
IAR011	Determine Correct data
IAR012	Determine data application
IAR013	Determine design specific
IAR014	Determine fabrication specification
IAR015	Determine process specific
IAR016	Determine regulatory requirement
IAR017	Determine regulatory requirements
IAR018	Determine repair parameters
IAR019	Determine repair requirements
IAR020	Interpret data
IAR021	Interpret regulations
IAR022	Recall alteration / design fundamentals
IAR023	Recall engine repair fundamentals
IAR024	Recall fundamental inspection principles - airframe / engine
IAR025	Recall MEL requirements
IAR026	Recall principles of corrosion control
IAR027	Recall principles of sheet metal forming
IAR028	Recall principles of system fundamentals
IAR029	Recall principles of weight and balance
IAR030	Recall regulatory requirements
IAR031	Recall regulatory specific
IAR032	Recall repair fundamentals

LEARNING STATEMENT CODES and LEARNING STATEMENTS for Aviation Mechanic - General Exams

AMG001	Ability to draw / sketch repairs / alterations
AMG002	Calculate center of gravity
AMG003	Calculate weight and balance
AMG004	Determine correct data
AMG005	Determine regulatory requirement.
AMG006	Interpret drag ratio from charts
AMG007	Recall aerodynamic fundamentals
AMG008	Recall air density
AMG009	Recall aircraft cleaning - materials / techniques
AMG010	Recall aircraft component markings
AMG011	Recall aircraft control cables - install / inspect / repair / service
AMG012	Recall aircraft corrosion - principles / control / prevention
AMG013	Recall aircraft drawings - detail / assembly
AMG014	Recall aircraft drawings / blueprints - lines / symbols / sketching
AMG015	Recall aircraft electrical system - install / inspect / repair / service
AMG016	Recall aircraft engines - performance charts
AMG017	Recall aircraft hardware - bolts / nuts / fasteners / fittings / valves
AMG018	Recall aircraft instruments - tachometer indications / dual tachometers
AMG019	Recall aircraft metals - inspect / test / repair / identify / heat treat
AMG020	Recall aircraft metals - types / tools / fasteners
AMG021	Recall aircraft publications - aircraft listings
AMG022	Recall aircraft records - required / destroyed
AMG023	Recall aircraft repair - major
AMG024	Recall airframe - inspections
AMG025	Recall airworthiness certificates - validity / requirements
AMG026	Recall ATA codes
AMG027	Recall basic physics - matter / energy / gas
AMG028	Recall data - approved
AMG029	Recall dissymmetry
AMG030	Recall effects of frost / snow on airfoils
AMG031	Recall electrical system - components / operating principles / characteristics / symbols
AMG032	Recall environmental factors affecting maintenance performance
AMG033	Recall external loading
AMG034	Recall flight characteristics - autorotation / compressibility
AMG035	Recall flight operations - air taxi
AMG036	Recall fluid lines - install / inspect / repair / service
AMG037	Recall fluid lines - material / coding
AMG038	Recall forces acting on aircraft - angle of incidence
AMG039	Recall forces acting on aircraft - yaw / adverse yaw
AMG040	Recall fuel - types / characteristics / contamination / fueling / defueling / dumping
AMG041	Recall fundamental inspection principles - airframe / engine
AMG042	Recall fundamental material properties
AMG043	Recall generator system - components / operating principles / characteristics
AMG044	Recall geometry

AMG045	Recall ground operations - start / move / service / secure aircraft
AMG046	Recall helicopter engine control system
AMG047	Recall helicopter flight controls
AMG048	Recall information on an Airworthiness Directive
AMG049	Recall instrument panel mounting
AMG050	Recall maintenance error management
AMG051	Recall maintenance publications - service / parts / repair
AMG052	Recall maintenance resource management
AMG053	Recall mathematics - percentages / decimals / fractions / ratio / general
AMG054	Recall penalties - falsification / cheating
AMG055	Recall physics - work forces
AMG056	Recall pitch control - collective / cyclic
AMG057	Recall precision measuring tools - meters / gauges / scales / calipers
AMG058	Recall reciprocating engine - components / operating principles / characteristics
AMG059	Recall regulations - aircraft inspection / records / expiration
AMG060	Recall regulations - aircraft operator certificate
AMG061	Recall regulations - aircraft registration / marks
AMG062	Recall regulations - Airworthiness Directives
AMG063	Recall regulations - airworthiness requirements / responsibilities
AMG064	Recall regulations - certificate of maintenance review requirements
AMG065	Recall regulations - Certificate of Release
AMG066	Recall regulations - certification of aircraft and components
AMG067	Recall regulations - change of address
AMG068	Recall regulations - check periods
AMG069	Recall regulations - determine mass and balance
AMG070	Recall regulations - display / inspection of licenses and certificates
AMG071	Recall regulations - emergency equipment
AMG072	Recall regulations - flight / operating manual marking / placard
AMG073	Recall regulations - housing and facility requirements
AMG074	Recall regulations - instrument / equipment requirements
AMG075	Recall regulations - maintenance control / procedure manual
AMG076	Recall regulations - maintenance reports / records / entries
AMG077	Recall regulations - maintenance requirements
AMG078	Recall regulations - minimum equipment list
AMG079	Recall regulations - minor / major repairs
AMG080	Recall regulations - persons authorized for return to service
AMG081	Recall regulations - persons authorized to perform maintenance
AMG082	Recall regulations - privileges / limitations of maintenance certificates / licenses
AMG083	Recall regulations - privileges of approved maintenance organizations
AMG084	Recall regulations - reapplication after revocation / suspension
AMG085	Recall regulations - reporting failures / malfunctions / defects
AMG086	Recall regulations - return to service
AMG087	Recall regulations - special airworthiness certificates / requirements
AMG088	Recall regulations - special flight permit
AMG089	Recall regulations - weighing an aircraft
AMG090	Recall repair fundamentals - turnbuckles
AMG091	Recall rotor system - components / operating principles / characteristics

AMG092	Recall rotorcraft vibration - characteristics / sources
AMG093	Recall starter / ignition system - components / operating principles / characteristics
AMG094	Recall starter system - starting procedures
AMG095	Recall turbine engines - components / operational characteristics / associated instruments
AMG096	Recall turbine engines - install / inspect / repair / service / hazards
AMG097	Recall type certificate data sheet (TCDS) / supplemental type certificate (STC)
AMG098	Recall welding types / techniques / equipment
AMG099	Recall work / power / force / motion
AMG100	Recall mathematics – extract roots / radicals / scientific notation
AMG101	Recall positive / negative algebraic operations – addition / subtraction / multiplication / division
AMG102	Recall aircraft electrical circuit diagrams – read / interpret / troubleshoot
AMG103	Define maintenance resource management
AMG104	Recall human reliability in maintenance errors
AMG105	Recall environmental factors leading to maintenance errors
AMG106	Recall fatigue in maintenance errors causes / interventions
AMG107	Recall error management
AMG108	Recall maintenance resource management
AMG109	Recall error management in shift turnover
AMG110	Recall error capture / duplicate inspection
AMG111	Recall ergonomic interventions to maintenance errors
AMG112	Recall interventions to prevent cross-connection maintenance errors
AMG113	Recall interventions to prevent shift / task turnover errors
AMG115	Recall environmental factors affecting maintenance performance – lighting / temperature / noise / air quality
AMG116	Recall error intervention – interruptions / access

LEARNING STATEMENT CODES and LEARNING STATEMENTS for Aviation Mechanic - Airframe Exams

AMA001	Recall aerodynamic fundamentals
AMA002	Recall air conditioning system - components / operating principles / characteristics
AMA003	Recall aircraft component markings
AMA004	Recall aircraft components material - flame resistant
AMA005	Recall aircraft cooling system - charging / leaking / oil / pressure / water
AMA006	Recall aircraft cooling system - components / operating principles / characteristics
AMA007	Recall aircraft corrosion - principles / control / prevention
AMA008	Recall aircraft engines - indicating system
AMA009	Recall aircraft exterior lighting - systems / components
AMA010	Recall aircraft flight indicator system
AMA011	Recall aircraft hardware - bolts / nuts / fasteners / fittings / valves
AMA012	Recall aircraft heating system - exhaust jacket inspection
AMA013	Recall aircraft instruments - install / inspect / adjust / repair / markings
AMA014	Recall aircraft instruments - types / components / operating principles / characteristics
AMA015	Recall aircraft lighting - install / inspect / repair / service
AMA016	Recall aircraft metals - inspect / test / repair / identify
AMA017	Recall aircraft metals - types / tools / fasteners
AMA018	Recall aircraft warning systems - navigation / stall / takeoff
AMA019	Recall airframe - inspections
AMA020	Recall airframe - repair / component installation
AMA021	Recall airframe design - structures / components
AMA022	Recall alternators - components / operating principles / characteristics
AMA023	Recall antenna system - install / inspect / repair / service
AMA024	Recall anti-icing / deicing - methods / systems
AMA025	Recall autopilot - components / operating principles / characteristics
AMA026	Recall autopilot - install / inspect / repair / service
AMA027	Recall avionics - components / operating principles / characteristics
AMA028	Recall avionics - install / inspect / repair / service
AMA029	Recall basic hand tools / torque values
AMA030	Recall batteries - capacity / charging / types / storage / rating / precautions
AMA031	Recall brake system - components / operating principles / characteristics
AMA032	Recall brake system - install / inspect / repair / service
AMA033	Recall carburetor - icing / anti-icing
AMA034	Recall chemical rain repellant
AMA035	Recall combustion heaters - components / operating principles / characteristics
AMA036	Recall compass - components / operating principles / characteristics
AMA037	Recall composite materials - types / repairs / techniques / processes
AMA038	Recall control cables - install / inspect / repair / service
AMA039	Recall DC electric motors - components / operating principles / characteristics
AMA040	Recall dope and fabric - materials / techniques / hazards
AMA041	Recall electrical system - components / operating principles / characteristics / symbols
AMA042	Recall electrical system - install / inspect / repair / service
AMA043	Recall electronic test equipment

AMA044 Recall Emergency Locator Transmitter (ELT) - operation / battery / testing
AMA045 Recall fiberglass - install / troubleshoot / service / repair
AMA046 Recall fire detection system - types / components / operating principles / characteristics
AMA047 Recall fire detection systems - install / inspect / repair / service
AMA048 Recall fire extinguishing systems - components / operating principles / characteristics
AMA050 Recall flight characteristics - longitudinal stability / instability
AMA051 Recall fluid lines - material / coding
AMA052 Recall fuel - types / characteristics / contamination / fueling / defueling / dumping
AMA053 Recall fuel / oil - anti-icing / deicing
AMA054 Recall fuel system - components / operating principles / characteristics
AMA055 Recall fuel system - install / troubleshoot / service / repair
AMA056 Recall fuel system - types
AMA057 Recall fuel/air mixture - idle rich mixture - RPM rise
AMA058 Recall fundamental material properties
AMA059 Recall fuselage stations
AMA060 Recall helicopter control system
AMA061 Recall helicopter control system - collective
AMA062 Recall helicopter drive system - free wheeling unit
AMA063 Recall hydraulic systems - components / operating principles / characteristics
AMA064 Recall hydraulic systems - fluids
AMA065 Recall hydraulic systems - install / inspect / repair / service
AMA066 Recall instrument panel installation - shock mounts
AMA067 Recall instruments - manifold pressure indicating system
AMA068 Recall landing gear system - components / operating principles / characteristics
AMA069 Recall landing gear system - install / inspect / repair / service
AMA070 Recall maintenance publications - service / parts / repair
AMA071 Recall navigation / communication systems - types / operational characteristics
AMA072 Recall oxygen system - components / operating principles / characteristics
AMA073 Recall oxygen system - install / inspect / repair / service / precautions
AMA074 Recall oxygen system - quality / types / contamination / cylinders / pressure
AMA075 Recall physics - work forces
AMA076 Recall pitot-static system - components / operating principles / characteristics
AMA077 Recall pitot-static system - install / inspect / repair / service
AMA078 Recall plastic fundamentals - installation / cleaning / repair / characteristics
AMA079 Recall pneumatic system - components / operating principles / characteristics
AMA080 Recall pressurization system - components / operating principles / characteristics
AMA081 Recall primary flight controls - inspect / adjust / repair
AMA082 Recall primary flight controls - types / purpose / functionality
AMA083 Recall radar altimeter - indications
AMA084 Recall radar altimeter - signals
AMA085 Recall radio system - components / operating principles / characteristics
AMA086 Recall radio system - install / inspect / repair / service
AMA087 Recall radio system - license requirements / frequencies
AMA088 Recall regulations - airworthiness requirements / responsibilities
AMA089 Recall regulations - maintenance reports / records / entries

AMA090 Recall regulations - privileges / limitations of maintenance certificates / licenses
AMA091 Recall rotor system - components / operating principles / characteristics
AMA092 Recall secondary flight control system - inspect / adjust / repair
AMA093 Recall secondary flight control system - types / purpose / functionality
AMA094 Recall sheet metal fabrication - blueprints / shaping / construction
AMA095 Recall smoke detection systems - types / components / operating principles / characteristics
AMA096 Recall static pressure system - install / inspect / repair / service
AMA097 Recall tires - install / inspect / repair / service / storage
AMA098 Recall turbine engines - components / operational characteristics / associated instruments
AMA099 Recall type certificate data sheet (TCDS) / supplemental type certificate (STC)
AMA100 Recall weight and balance - equipment installation / CG / general principles
AMA101 Recall welding / soldering - types / techniques / equipment
AMA102 Recall wooden components - failures / decay / patching / gluing / substitutions

LEARNING STATEMENT CODES and LEARNING STATEMENTS for Aviation Mechanic - Powerplant Exams

AMP001	Recall aircraft alternators - components / operating principles / characteristics
AMP002	Recall aircraft batteries - capacity / charging / types / storage / rating / precautions
AMP003	Recall aircraft carburetor - icing / anti-icing
AMP004	Recall aircraft component markings
AMP005	Recall aircraft cooling system - components / operating principles / characteristics
AMP006	Recall aircraft electrical system - install / inspect / repair / service
AMP007	Recall aircraft engine - inspections / cleaning
AMP008	Recall aircraft engines - components / operating principles / characteristics
AMP009	Recall aircraft engines - indicating system
AMP010	Recall aircraft fire classifications
AMP011	Recall aircraft hydraulic systems - components / operating principles / characteristics
AMP012	Recall aircraft instruments - types / components / operating principles / characteristics / markings
AMP013	Recall airflow systems - Bellmouth compressor inlet
AMP014	Recall airframe - inspections
AMP015	Recall altitude compensator / aneroid valve
AMP016	Recall anti-icing / deicing - methods / systems
AMP017	Recall Auxiliary Power Units - components / operating principles / characteristics
AMP018	Recall Auxiliary Power Units - install / inspect / repair / service
AMP019	Recall axial flow compressor - components / operating principles / characteristics
AMP020	Recall basic physics - matter / energy / gas
AMP021	Recall carburetor - effects of carburetor heat / heat control
AMP022	Recall carburetors - components / operating principles / characteristics
AMP023	Recall carburetors - install / inspect / repair / service
AMP024	Recall data - approved
AMP025	Recall DC electric motors - components / operating principles / characteristics
AMP026	Recall electrical system - components / operating principles / characteristics
AMP027	Recall engine cooling system - components / operating principles / characteristics
AMP028	Recall engine cooling system - install / inspect / repair / service
AMP029	Recall engine lubricating oils - function / grades / viscosity / types
AMP030	Recall engine lubricating system - components / operating principles / characteristics
AMP031	Recall engine lubricating system - install / inspect / repair / service
AMP032	Recall engine operations - thrust / thrust reverser
AMP033	Recall engine pressure ratio - EPR
AMP034	Recall fire detection system - types / components / operating principles / characteristics
AMP035	Recall fire detection systems - install / inspect / repair / service
AMP036	Recall fire extinguishing systems - components / operating principles / characteristics
AMP037	Recall float type carburetor - components / operating principles / characteristics
AMP038	Recall float type carburetor - install / inspect / repair / service
AMP039	Recall fuel - types / characteristics / contamination / fueling / defueling / dumping
AMP040	Recall fuel / oil - anti-icing / deicing

AMP041 Recall fuel system - components / operating principles / characteristics
AMP042 Recall fuel system - install / troubleshoot / service / repair
AMP043 Recall fuel system - types
AMP044 Recall generator system - components / operating principles / characteristics
AMP045 Recall information on an Airworthiness Directive
AMP046 Recall magneto - components / operating principles / characteristics
AMP047 Recall magneto - install / inspect / repair / service
AMP048 Recall maintenance publications - service / parts / repair
AMP049 Recall piston assembly - components / operating principles / characteristics
AMP050 Recall powerplant design - structures / components
AMP051 Recall pressure type carburetor - components / operating principles / characteristics
AMP052 Recall propeller system - install / inspect / repair / service
AMP053 Recall propeller system - types/ components / operating principles / characteristics
AMP054 Recall radial engine - components / operating principles / characteristics
AMP055 Recall radial engine - install / inspect / repair / service
AMP056 Recall reciprocating engine - components / operating principles / characteristics
AMP057 Recall reciprocating engine - install / inspect / repair / service
AMP058 Recall regulations - maintenance reports / records / entries
AMP059 Recall regulations - privileges / limitations of maintenance certificates / licenses
AMP060 Recall regulations - privileges of approved maintenance organizations
AMP061 Recall rotor system - components / operating principles / characteristics
AMP062 Recall sea level - standard temperature / pressure
AMP063 Recall starter / ignition system - components / operating principles / characteristics
AMP064 Recall starter / ignition system - install / inspect / repair / service
AMP065 Recall starter system - starting procedures
AMP066 Recall thermocouples - components / operating principles / characteristics
AMP067 Recall thermocouples - install / inspect / repair / service
AMP068 Recall turbine engines - components / operational characteristics / associated instruments
AMP069 Recall turbine engines - install / inspect / repair / service / hazards
AMP070 Recall turbocharger system - components / operating principles / characteristics
AMP071 Recall turbojet - components / operating principles / characteristics
AMP072 Recall type certificate data sheet (TCDS) / supplemental type certificate (STC)
AMP073 Recall welding types / techniques / equipment

U.S. Department
of Transportation
Federal Aviation
Administration

R&D Control Study: Plan for Future Jet Fuel Distribution Quality Control and Description of Fuel Properties Catalog

Broad Agency Announcement
Alternative Aviation Fuels

Submitted by Metron Aviation, Inc.

DOT/FAA/AEE/2014-11
DOT-VNTSC-FAA-14-11

The National Transportation Systems Center

The Broad Agency Announcement Alternative Aviation Fuels was a solicitation released by the U.S. Department of Transportation Research and Innovative Technology Administration (RITA) / John A. Volpe National Transportation Systems Center with funding provided by the FAA's Office of Environment and Energy. Work under the BAA was performed in four key technical areas including: Future alternative jet fuels development and testing; alternative jet fuel quality and performance control R&D study; alternative jet fuel sustainability studies; and alternative jet fuel performance testing by industry. The report presented herein is the final report deliverable submitted by Metron Aviation, Inc. for the project conducted under alternative jet fuel quality and performance control R&D study.

This project was conducted under Volpe solicitation number DTRT57-11-R-20001 and under contract number DTRT57-11-C-10051. This is report number DOT/FAA/AEE/2014-11 by the FAA's Office of Environment and Energy. It is report number DOT-VNTSC-FAA-14-11 by the Volpe National Transportation Systems Center.

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Alternative Aviation Fuels BAA

B. Advanced Jet Fuel Quality and Performance Control Research and Development (R&D) Study

R&D Control Study: Plan for Future Jet Fuel Distribution Quality Control and Description of Fuel Properties Catalog

Bruno Miller, Donovan Johnson, Terry Thompson
Metron Aviation

Frank L. Rosenberg, Judith Driver, Gerard P. Biscardi
ACA Associates

Madalina K. Mohtadi, Nabil J. Mohtadi
Nobil Petroleum Testing, Inc.

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(Updated May 9th, 2014)

Metron Aviation, Inc.
45300 Catalina Court, Suite 101
Dulles, VA 20166

Contents

1 Introduction

1.1 Background

In accordance with the Federal Aviation Administration's (FAA) NextGen Implementation Plan (NGIP), decreasing the environmental impact in the National Airspace System (NAS) while allowing for an increase in traffic is of strategic importance. The use of alternative fuels is one of the means that has the potential to limit the impact of aviation emissions on global climate. In addition, alternative fuels can contribute to energy security through diversification away from petroleum-based fuels. The support of the FAA and the John A. Volpe Transportation Systems Center (Volpe Center), part of the U.S. Department of Transportation's Research and Innovative Technology Administration (RITA), as well as support of the FAA through the Commercial Aviation Alternative Fuels Initiative (CAAFI), is of integral importance to the efforts of many stakeholders to produce and commercialize emissions-cutting alternative aviation fuels.

The impending introduction of alternative aviation fuels has the potential for introducing materials into the aviation fuel distribution system that have not been present historically. If not handled properly, there is the potential for these materials to impact aircraft operations as well as the fuel transportation and handling infrastructure. Furthermore, many of these alternative fuels will be produced by new entrants that have little or no experience in the monitoring and testing of aviation fuels as they enter the jet fuel supply chain. As a result, it is considered important to re-examine the existing framework for managing the fuel handling process to make sure that it is adequate for the new circumstances. A key aspect for the successful adoption of alternative aviation fuels is that they must be 100% compatible with the existing jet fuel infrastructure and equipment; therefore, the testing and certification framework assures users that these fuels are, indeed, 100% compatible.

1.2 Introduction to alternative jet fuels

In general terms, alternative jet fuels have the same performance characteristics as petroleum-based jet fuels, such as Jet A and JP 8, but are produced from non-petroleum feedstock using a number of different technologies. Feedstock for alternative jet fuels can be renewable (e.g., plant oils, animal fats, and biomass such as crop residues, wood chips, and prairie grasses) and non-renewable (e.g., coal and natural gas). Alternative jet fuels have different environmental and economic characteristics depending on the feedstock and technology process utilized.

There are several combinations of feedstock and production technologies, or "pathways," to produce alternative jet fuel, including:

- Fischer-Tropsch (FT) process which can be used to convert coal, natural gas, or biomass into liquid fuels such as diesel and alternative jet fuel.
- Hydroprocessed Esters and Fatty Acids (HEFA) process in which plant oils or animal fats can be converted into liquid fuels.
- Alcohols-to-Jet (ATJ) process that uses alcohols as feedstock to produce alternative jet fuel and other by-products.

The above processes are at different stages of maturity. FT fuels have been produced for decades; in fact, jet fuel from coal using the FT process has been in use in South Africa for many years and it was the first alternative jet fuel to be approved for use on aircraft. The HEFA process is more recent and was just approved for use on aircraft in 2011. The ATJ process is still in development and it is anticipated that ATJ fuels will be approved for use on aircraft in the 2014 timeframe. There are other pathways for producing alternative jet fuel, such as fermentation, catalytic conversion, and pyrolysis that are expected to undergo the approval process in years to come.

1.3 "Drop-in" alternative jet fuels

The aviation industry, including airlines, fuel distributors, and equipment manufacturers, have made it a priority to ensure that alternative jet fuels can be used in the existing infrastructure, airframes, engines, and other equipment without the need for any modifications. In other words, the industry wants alternative jet fuels that are fully interchangeable, or "drop-in," with petroleum-based fuels. Drop-in alternative jet fuels can, therefore, be used alongside conventional jet fuel or in isolation without changes to any infrastructure or equipment.

It is important to note the difference between drop-in blends and drop-in "neat" alternative jet fuel. Drop-in neat alternative fuels are defined as "a substitute for conventional jet fuel that is completely interchangeable and compatible with conventional jet fuel. A drop-in neat fuel does not require adaptation of the aircraft/engine fuel system or the fuel distribution network, and can be used "as is" on currently flying turbine-powered aircraft in pure form and/or blended in any amount with other drop-in neat, drop-in blend, or conventional jet fuels"[1]. As will be discussed in more detail in section 3, jet fuel is a complex mixture of different hydrocarbons, including iso and normal paraffins, napthenes, and aromatics. Some of the processes for alternative jet fuel do not produce as end produce a fuel that can replicate completely the composition and performance characteristics of conventional jet; therefore, those fuels need to be blended with conventional jet fuel to ensure the required specification is met. Those fuel blends, assuming they meet the required specifications, are known as drop-in blends.

1.4 Objective of the study

The main objective of this study is to investigate and provide recommendations for any unique quality control requirements that the production and distribution of alternative jet fuels may require, ultimately producing a quality control handbook for alternative jet fuel entrants and others along the supply chain. As experience is gained with the production and distribution of

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[1] http://caafi.org/resources/glossary.html#D

alternative jet fuels, the quality control of those fuels can be examined relative to this handbook by the ASTM Aviation Fuels Subcommittee and by stakeholders that are engaged in the supply chain that produces, distributes, and uses jet fuel.

To reach the objective stated above, this study will a) highlight best practices for maintaining quality control of jet fuel, b) identify gaps in current quality and performance procedures that may emerge with the introduction of alternative fuels, c) suggest areas for improvement in current jet fuel quality control practices to accommodate the introduction of alternative fuels, and d) provide recommendations for an improved method of collection of fuel property and quality measurements.

1.5 Organization of the report

The report is organized in five main sections plus appendices and other supporting documentation. The main sections are described below:

Section 2, "Overview of Jet Fuel Specification and Standards," describes the system and organizations that issue specifications for jet fuel and the roles that different stakeholders play.

Section 3, "Jet Fuel Specifications and Testing Procedures," presents detailed information on jet fuel specifications and associated testing procedures.

Section 4, "Quality Control along the Supply Chain," describes the quality control procedures along the supply chain of jet fuel, from refinery production to aircraft delivery.

Section 5, "Considerations Regarding the Introduction of Alternative Fuels," discusses recommendations to the quality control system to address potential gaps in the existing jet fuel quality control system because of the introduction of alternative fuels.

Section 6, " Fuel Properties Catalog," describes the elements of a proposed fuel properties catalog, data requirements, and collection methods.

2 Overview of Jet Fuel Specification and Standards

Specifications and handling procedures for jet fuels are much more tightly controlled than for other fuel products, because minor changes in fuel properties, cleanliness, or contaminant levels can have drastic, unanticipated effects on engine performance. Based on many years of experience, a complex quality control system has been created. It starts with jet fuel certification at the production facility and continues along the entire supply chain from the refinery to the aircraft. This section provides an overview of jet fuel standards, certification requirements, and the role of different entities and organizations. A summary of the main organizations and documents involved in jet fuel quality control procedures discussed here is shown in Table 1:

Table 1: Summary of Common Documents Used in the U.S. Regarding Specification and Recommended Practices for Handling Jet Fuel

Organization	Document	Title
Jet Fuel Production Specification*		
ASTM	D-1655	Standard Specification for Aviation Turbine Fuels
ASTM	D-7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
U.K. Ministry of Defence	DEFSTAN 91-91	Turbine Fuel, Aviation Kerosine Type, Jet A1
Supply Chain Recommended Practices		
API	API 1543	Documentation, Monitoring and Laboratory Testing of Aviation Fuel During Shipment from Refinery to Airport
API	API 1540	Design, construction, operation and maintenance of aviation fuelling facilities (Model code of safe practice Part 7)
EI/HM 50	EI/HM	Guideline for the cleaning of tanks and lines for marine tank vessels carrying petroleum and refined products.
A4A	ATA 103	Standards for Jet Fuel Quality Control at Airports
IATA	IATA Fuel Quality Pool	Control of Fuel Quality & Fueling Safety Standards
JIG	JIG Sections 1 to 4	Guidelines for Aviation Fuel Quality Control and Operating Procedures for Joint Into-Plane Fueling Services
API	API 1595	Design, Construction, Operation, Maintenance, and Inspection of Aviation Pre-Airfield Storage Terminals
EI	EI 1530	Quality assurance requirements for the manufacture, storage and distribution of aviation fuels to airport
ICAO	Doc 9977, AN/489	Manual on Civil Aviation Jet Fuel Supply
SAE Aerospace	SAE- AS 6401	Storage, Handling and Distribution of Jet Fuels at Airports.

*There are other country or region specific aviation fuel specifications, but this study focuses on ASTM and DEFSTAN 91-91 since these are the most common in the U.S.

2.1 Jet fuel specification

At the top of the quality control pyramid for aviation fuel is the set of standards jet fuel must meet before it leaves the production facility and enters the supply chain. Jet fuel standards are revisited frequently to ensure they meet the requirements of current engines, and have evolved along with the development of the jet engine (see Section 3). Producers are required to test all jet fuel as it leaves the facility and to certify that it satisfies the appropriate specification (see Section 4.2). The quality control system in the supply chain relies upon this certification, because downstream tests do not cover all the standards mandated for the manufacturer unless the fuel fails a test at some point. In such case, the jet fuel needs to be fully re-tested and re-certified.

Specifications for jet fuel are established by standard-setting organizations such as ASTM International (ASTM) in the United States, and the United Kingdom's Ministry of Defence (DEFSTAN), which are recognized by aircraft and engine manufacturers and regulatory agencies around the world. Here, we focus mainly on the ASTM standards that are used for all commercial aviation fuels used in the United States; DEFSTAN and other standards are referenced but not discussed in as much detail.

In addition to setting performance standards, standard-setting organizations also specify which methods are acceptable to test the fuel. The most widely used commercial jet fuel specifications in use today, **ASTM D1655** *Standard specification for Aviation Turbine Fuels* (ASTM 2011) and **DEFSTAN 91-91** *Turbine Fuel, Aviation Kerosine Type, Jet A1* (MOD 2008), identify specific test methods to measure fuel performance. There are a few differences between the performance measures of the two standards, but the main differences have been with approved testing methods. The U.K. Ministry of Defence and ASTM have always cooperated with the intent of approving and incorporating each other's test methods to create a single global specification with a consolidated listing of approved instruments and methods. Their intent of recognizing and accommodating the availability of different testing equipment and technologies in different regions of the world will soon become reality as ASTM is balloting the addition of Institute of Petroleum (IP) methods in ASTM D1655 with the note that the ASTM methods will still be the reference methods in the US.

Other entities, such as the International Air Transport Association (IATA) and the Joint Inspection Group (JIG), issue recommended practices that are based largely on ASTM and DEFSTAN specifications. More information on these entities is presented below in Section 2.3.

2.1.1 ASTM International (ASTM)

ASTM develops and publishes the specification for turbine fuels that govern all jet fuels used in the United States. ASTM follows a consensus-based process for developing specifications. It has a long history going back to its origin in 1899 with Steel Industry Specifications for the railroad industry (ASTM 2001c). In 1921, the first petroleum standard was issued as **ASTM D86** *Method for Distillation of Petroleum Products at Atmospheric Pressure*, which became one of the most used ASTM standards and became a joint ASTM/Institute of Petroleum standard (Totten 2004). The second was **ASTM D445** *Method for Kinematic Viscosity of Transparent and Opaque Liquids*, which covered a long list of products including jet fuel, aircraft turbine lubricants, automotive and domestic fuel oils, diesel fuels, and hydraulic oils. D1655 is the standard for jet fuel in use today. It was first issued in 1959 and remains the exclusive specification for aviation turbine fuel in the United States. Since 1959, it has been reviewed, balloted, and revised to include and reflect the changes in quality requirements due to turbine engine modifications, new materials, and design improvements.

D1655 covers Jet A fuel, the most prevalent jet fuel in the United States, and Jet A1 fuel, which is used in most of the rest of the world. The only difference between Jet A and Jet A1 is that the freezing point of Jet A is -40 degrees Celsius versus the freezing point for Jet A1 of -47 degrees Celsius. D1655 also covers fuels from non-conventional petroleum sources such as oil sands or shale, and following DEFSTAN's lead, it was revised to include SASOL semi-synthetic fuel made from coal.

ASTM D7566 *Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons* (ASTM 2012) is the specification that applies to alternative jet fuels. To comply with ASTM D7566, neat alternative fuels must be blended with conventional fuel in a percentage approved by this standard. Since its approval in 2009 until its revision in 2013, this percentage has been set not to exceed 50% alternative fuel. It is important to note that D7566 Table 1 "Detailed Requirements of Aviation Turbine Fuels Containing Synthesized Hydrocarbons" (part 1 and 2) applies only at the point of blending of neat alternative fuel with conventional jet fuel. From that point onwards, the fuel is re-designated as D1655 fuel and treated as such throughout the supply chain.

The novelty of D7566 is that it includes two types of specifications: the specification for the blend of alternative and conventional fuel (Table 1 of D7566), and also the specification for neat alternative fuels, which are approved by production type. Individual process types are approved under Annexes to D7566; any new candidates for qualification and approval must follow the process described in ASTM D4054 -*Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives* [ASTM 2009]. The initial issue of D7566 approved in 2009 provides criteria for the production, distribution, and use of aviation turbine engine fuel produced from coal, natural gas or biomass using the Fischer-Tropsch process. In 2011, after two years of review, a new D7566 annex covering hydroprocessed esters and fatty acids (HEFA) was approved. It is expected that FT and HEFA will be followed by approvals for other production processes as they are developed, such as alcohol-to-jet (ATJ). Based on CAAFI's Fuel Readiness Level,[2] ATJ is expected to be qualified for approval by 2014.

[2] http://caafi.org/information/fuelreadinesslevel.html

2.1.2 United Kingdom Ministry of Defence (MOD)

Specifications published by MOD are used for most civil aviation fuels outside the United States. The first British jet engine fuel specification was introduced at the end of World War II. Following amendments and the addition of increasingly stringent requirements, the U.K. standard has evolved into today's commercial specification DEFSTAN 91-91.

The MOD was instrumental in pioneering the use of jet fuel from non-petroleum sources with the inclusion of sole site approval for SASOL's synthetic kerosene blends in DEFSTAN 91-91 in 1998. In 2008, following years of safe use of the blended fuel, DEFSTAN 91-91 approved SASOL's unblended synthetic jet fuel as Jet A-1 fuel for commercial use in all types of turbine aircraft (Sasol 2011).

2.1.3 Canadian General Standards Board (CAN CGSB)

The CAN CGSB is accredited as a Standards Development Organization by the Standards Council of Canada. Some of its specifications related to jet fuel include:

- CAN CGSB - 3.22, which covers wide-cut fuel (JetB) use in parts of Canada and Alaska
- CAN/CGSB - 3.23, which includes grades Jet A and Jet A-1
- CAN/CGSB - 3.24, which includes military grades JP-5 and JP-8

2.1.4 Russian specifications

The Russian Specifications are issued by Russia State Standard Committee. The Russian specification GOST 10227 covers the light kerosene-type fuel (TS-1 and RT) used in the countries members of Commonwealth of Independent States and parts of Eastern Europe. It is the only specification that uses different test methods.

2.1.5 Chinese specifications

Chinese specifications are issued by China's National Technology Supervisory Bureau. The GB6537 standard covers "No.3 Jet Fuel" which is basically equivalent to Jet A1 and is the predominant kerosene used in China.

2.2 Role of other entities

2.2.1 Regulatory Agencies

Regulatory agencies are involved in ensuring the ongoing safety of civil aviation, through rigorous processes of testing and certification of aircraft, issuing operating certificates to air carriers, and by ensuring that airports operate their fuel storage and delivery systems safely.

Aircraft and engines are generally certified for airworthiness by the national civil aviation authority in the country of manufacture. In the U.S., this is the Federal Aviation Administration (FAA). Federal Aviation Regulation 14CFR Part 25 (Airworthiness Standards: Transport Category Airplanes, 2010) include procedures to be followed for airworthiness certification of aircraft and 14CFR Part 33 provides airworthiness standards for certification of engines. In the case of aircraft engines, this includes extensive testing carried out by the original equipment manufacturer (OEM) and witnessed by the FAA, and when testing is successfully completed, a

“Type Certificate” is issued for the engine. This engine Type Certificate includes, among other requirements, the specification for the jet fuel approved by the OEM to be used in that equipment. Thus, the FAA does not directly regulate fuel standards; instead it refers to them in Type Certificates (Airworthiness Standards: Aircraft Engines, 2010).

Furthermore, the FAA also issues Operating Certificates to airlines based in part on their operating manuals which include engine operating manuals that specify what fuel must be used in the aircraft. At regular intervals, the FAA conducts safety inspections of airlines to ensure they are operating in accordance with their operating certificate (FAR-121), which include a check on whether they have systems in place to ensure fuel being used complies with the manual specification, including being fit for use. Once again, the FAA refers to the ASTM specification rather than being directly involved in setting or approving the standard (FAA 2011).

2.2.2 Aircraft and Engine Manufacturers

Aircraft and engine manufacturers play a central role in the formulation of fuel performance standards developed and approved by the standard-setting organizations to ensure their products perform as advertised and are not harmed through the use of inappropriate fuels (ASTM D4054). Different engine manufacturers have their own specifications that are based on D1655 and DEFSTAN 91-91 and specific operating conditions for the equipment. This specification is included in the aircraft/engine operating manual and in the Aircraft Flight Manual (AFM) which must be followed by an aircraft operator to comply with their Operating Certificate.

2.3 Supply chain recommended practices

It is the responsibility of the final fuel delivery company to furnish on specification, “clean and dry” fuel to an airport. Organizations such as the American Petroleum Institute (API), the Energy Institute (EI) in the United Kingdom, and the Joint Inspection Group (JIG) have issued best practice handling procedures and testing guidelines to help achieve this goal, as discussed below.

2.3.1 American Petroleum Institute (API)/ Energy Institute (EI)

In the United States, the API published recommended practices for handling petroleum products. Starting in 2010, these publications have been taken over by the Energy Institute (EI 2011).

Publications of major interest to the aviation jet fuel community include:

API 1540 *Design, construction, operation and maintenance of aviation fuelling facilities* (API 1540): provides information for the proper siting, design, layout, and construction of aviation fueling facilities at the airport.

API 1543 *Documentation, Monitoring and Laboratory Testing of Aviation Fuel During Shipment from Refinery to Airport* (API 1543): discusses the fuel quality testing procedures necessary for the fuel to leave the refinery and flow through the supply chain to airport storage. The tests ensure that the product has not been contaminated or otherwise damaged in any way.

API 1595 *Design, Construction, Operation, Maintenance, and Inspection of Aviation Pre-Airfield Storage Terminals* (API 1595): describes best practices that should be followed in the handling of fuel and operation of storage facilities upstream of the airport.

EI 1530 *Quality assurance requirements for the manufacture, storage and distribution of aviation fuels to airport* (EI 2012): its stated objective is to provide a standard to help any company or organization involved in the production or handling of aviation fuel in the maintenance of aviation fuel quality. It covers the entire supply chain from point of manufacture to delivery to the airport. EI 1530 had not been released publicly at the time this report was prepared but a draft for stakeholder review was available.

2.3.2 Airlines for America (A4A)

To help ensure consistent fuel quality at airports throughout the U.S., airlines, under the auspices of their industry group Airlines for America (formerly known as Air Transport Association, ATA), organized a committee with representatives from airlines, oil companies and the independent airport fuel handling companies which created an all-encompassing standard fuel handling specification, known as ATA 103 (ATA 2009).

ATA 103 – *Standard for Jet Fuel Quality Control at Airports* (ATA 103): sets the standards not only for fuel quality control but for every aspect of getting fuel from the delivery point on the airport right up to the wing of the aircraft.

2.3.3 International Air Transport Association (IATA)

In its effort to institute global standards of fuel storage and handling, the IATA Fuel Quality Pool (IFQP) has set standards for fuel handling and inspected airports around the world (IATA 2011). IATA is currently updating the Provision Manual Standard 8 which is slated for publication in 2012. IATA is working with ICAO to implement these standards globally.

Furthermore, IATA published *Guidance Material for Aviation Turbine Fuels Specification* in 2008 which contains specifications for Jet A and Jet A1 based on both ASTM D1655 and DEFSTAN 91-91 (IATA 2008). It is intended to provide airlines a standard basis for jet fuel purchase contract specifications as IATA does not independently set fuel specifications.

2.3.4 International Civil Aviation Organization (ICAO)

ICAO recently published a *Manual on Civil Aviation Jet Fuel Supply(Doc 9977, AN/489)* to help member states, airlines, petroleum companies, and other stakeholders get a better and more uniform understanding of jet fuel quality control practices around the world (ICAO 2012). The document covers the handling of aviation fuels from the refinery production processes through the complete supply chain. It directs readers to the specific guidelines published by other agencies covering each segment of the supply chain (e.g., EI 1530, JIG, API 1543, API 1595, and SAE AS-6401). The document does not include information on alternative jet fuel.

2.3.5 Joint Inspection Group (JIG)

In 1974, a group of major oil companies formed JIG in order to develop a set of guidelines for handling aviation fuel at airports and upstream aviation fuel facilities (JIG 2011a). The intent was for these guidelines to be the basis to develop site-specific manuals at airports where joint fueling facilities were used. The Joint Guidelines include recommended practice for fuel sampling and testing, depot and fueling vehicle design features, and procedures for storage and delivery of aviation fuel to aircraft. These guidelines are updated regularly. At many commercial airports outside the U.S. where joint storage and hydrant systems are in place, airlines use the JIG Checklist to determine the quality system.

AFQRJOS – Aviation *Fuel Quality Requirements for Jointly Operated Systems* (JIG 2011b). This checklist combines the most stringent requirements of both ASTM D-1655 and DEFSTAN 91-91. One of its main benefits is that it broadens the approved test methods that can be used for the different quality tests, allowing a greater flexibility regarding approved equipment and technology.

2.3.6 SAE - Society of Automotive Engineers (1916)

SAE is an organization for engineering professionals in the aerospace, automotive, and commercial vehicle industries. The Society is a standards development organization for the engineering of powered vehicles, including cars, trucks, boats, aircraft, and others. SAE Aerospace Standards (AS) apply to missile, airframe, ground-support equipment, propulsion, propeller, and accessory equipment. Aerospace Recommended Practices (ARP) are recommendations for engineering practice, and are guidelines for design and production of aircraft and aircraft avionics systems. Aerospace Information Reports (AIR) contain generally accepted engineering data and information.

SAE Aerospace AS6401 - *Storage, Handling and Distribution of Jet Fuel at Airports* **-** was first issued in 2009. It is a very detailed guideline and aims to provide one single global standard for the handling of the aviation fuel, therefore to include all applicable guidelines published by others (EI/API, JIG, IATA, A4A) in a single publication. It covers the fuel supply chain from refinery certification to the wing of the aircraft.

3 Jet Fuel Specifications and Testing Procedures

This section describes the major characteristics of jet fuel that are addressed in jet fuel standards. We describe the performance characteristics that are required for a safe, effective jet fuel and briefly describe the tests that are specified in ASTM D1655 and D7566 to measure the fuel characteristics. Test methods are referred to by their title and code (e.g., DXXX). For more details on any tests, please visit the ASTM International website at: www.astm.org

3.1 Jet fuel performance characteristics

Jet fuel is a mixture of a large number (as many as thousands) of different hydrocarbon molecules, with carbon numbers mostly in the C_9-$C1_6$ range, a complex mixture of aliphatic and aromatic hydrocarbons and heteroatomic compounds, such as organonitrogen and organosulfur molecules. Jet fuels are composed mainly of three classes of organic compounds: about 60% iso and normal aliphatic alkanes (paraffins), about 20% cycloalkanes (napthenes), about 10-20% aromatics, and less than 1% olefins. The properties of each class of molecule influence the overall properties of the jet fuel and affect its performance in the turbine engine. When properties of jet fuels differ, it is because the fuels contain different proportions of compounds from these three classes. Furthermore, other properties of jet fuel are determined by individual components present in small, or trace amounts, and are not reflective of the typical composition of the mixture. The trace components may be present in the feedstock from which the jet fuel is produced or come from other sources such as additives or contaminants.

Modern analytical techniques are still not powerful enough to fully identify all the individual molecules that make up the jet fuel mixture. Therefore, jet fuel specifications and requirements are defined in terms of required performance rather than a strict target composition, although experience has proved that certain limits have to be set on certain classes of compounds.

It is important to understand that the specification for jet fuel is largely driven by the design of the jet engine and the fuel distribution system. To be acceptable for use on the current fuel infrastructure and equipment, any new fuel being considered must be capable of meeting the requirements specified for existing engine designs and existing fuel systems, in addition to environmental issues, such as limitation on sulfur content and other gas emissions. All key performance characteristics for jet fuel are translated and enforced by the specification requirements and they are measured by certain tests, as shown in Table 2:

Table 2: Performance Characteristics of Aviation Turbine Fuels. Source: ASTM D1655

Performance Characteristics	Test Method
Engine fuel system deposits and coke	Thermal stability
Combustion properties	Smoke point
	Aromatics
	Percent napthtalenes
Fuel metering and aircraft range	Density
	Net heat of combustion
Fuel atomization	Distillation
	Viscosity
Fluidity at low temperature	Freezing point
Compatibility with elastomer and the metals in the fuel system and turbine	Mercaptan sulfur
	Sulfur
	Copper strip corrosion
	Acidity
Fuel storage stability	Existent gum
Fuel handling	Flash point
	Static Electricity
	Water separation characteristics
	Free water and particulate contamination
	Particulate matter in fuel (contaminants)
	Membrane color ratings
	Undissolved water
Fuel lubricating ability (lubricity)	Fuel lubricity

Characteristics of jet fuels are discussed below:

3.1.1 Thermal stability

In normal operations, jet fuel is subject to temperature extremes between subzero temperatures in aircraft fuel tanks at high altitudes to very high temperatures in the combustor of the engine. In modern engines, fuel is used to absorb heat in different parts and stages prior to entering the combustor. At high temperatures, fuel can break down due to oxidation, which may be accelerated by the presences of certain dissolved metals, especially copper, that function as a catalyst. Thermal instability involves the formation of higher molecular weight compounds with limited fuel solubility, soluble gums, and, most critically, insoluble material that may either coat surfaces or form particulates. Commercial jet fuels should be thermally stable at temperature as high as 163 degrees C (325 degrees F).

The oxidative thermal stability is determined with the **Jet Fuel Thermal Oxidation Tests** (**D3241)**. It is a pass/fail run with the tube temperature at 260 degrees C to ensure compliance with minimum specification requirements.

3.1.2 Combustion

The combustion characteristics of a fuel depend largely on its molecular composition. Of the major organic class groups in jet fuel, paraffins have excellent burning properties, naphthenes have intermediate burning characteristics, closer to the paraffins, while aromatics have the least desirable combustion characteristics because they tend to burn with smoky flame and release a greater proportion of their chemical energy as undesirable radiation than other hydrocarbons. The specification limit for aromatics is a compromise between the combustion properties and the beneficial effect that the aromatics seem to have on certain fuel system seals. Similarly, for maintaining the desired combustion performance of the fuel, jet fuel specifications impose a limit on naphthalenes, which are heavy polycyclic aromatics (ASTM D1655 and DEFSTAN 91-91 have a limit of max 3% per volume for napthalenes).

Three combustion-related tests are: **Smoke Point (D1840); Percent Naphthalenes (D1840); and Aromatics content (D1319)**

3.1.3 Fuel metering and aircraft range

The overall design of aircraft and engines is based on the conversion of the heat of combustion of hydrocarbons in jet fuel into mechanical energy. A reduction in heat energy below the minimum specification would result in an increase in fuel consumption with corresponding loss of aircraft range and an increase in an airline's fuel cost.

Density (D1298, D4052) is a measure of fuel mass per unit volume, and is used for fuel load calculations. On the ground, jet fuel is bought on a volume basis, but in-aircraft fuel is measured by weight, so if fuel is of low density calculated loads may not be enough to complete the flight. Density is also useful in empirical assessment of heating value when used with other parameters, such as aniline point or distillation. For example, a low density may indicate low heating value per unit volume.

Net Heat of combustion (D4529, D3338, D4809) is the quantity of heat liberated by combustion of a unit quantity of fuel with oxygen. Heat of combustion directly affects the economics of engine performance. A reduction in heat energy would result into an increase in fuel consumption with corresponding loss or range. Refineries usually use the empirical calculation of the net heat of combustion based on correlations between sulfur content, gravity, volatility, and aromatics content.

3.1.4 Fuel atomization

Fuel volatility and ease of vaporization are affected by the hydrocarbon class type content of the jet fuel, and are determined by **Distillation (D86, D2887)** tests**.** The 10% distilled temperatures are limited to ensure easy starting. The Final boiling Point limit excludes heavier fractions that would be difficult to vaporize. **Viscosity at low temperature (D445)** is closely related to the pumpability characteristics over the temperature range. It is limited to ensure that proper fuel flow and atomization are maintained under all operating conditions and that fuel injection nozzles and system controls will operate at design conditions. Fuel viscosity can also influence the lubricating property of the fuel which affects the service life of fuel pumps.

3.1.5 Fluidity at low temperature

Jet fuel must have acceptable **freezing point (D5972, D7153, D7154, D2386**) and low temperature pumpability characteristics so that adequate fuel flow to the engine is maintained during long cruise periods at high altitudes. Freezing point is a property that depends on the molecular composition of the jet fuel: it increases with carbon number within each class, but is strongly influenced by molecular shape. Compounds with straight molecules such as normal paraffins and unsubstituted aromatics freeze at much higher temperatures than branched or circular compounds with the same carbon number. Normal paraffins in fuels have the highest freezing point, which means they will be the first to crystallize and come out of solution as wax crystals at low temperature, blocking fuel lines, filters, and nozzles (only 8-10% of normal paraffins in the fuel are required to form such a scenario).

3.1.6 Compatibility with elastomer and metals in the fuel system and engine

Aromatics (**D1319, D6379) -** Compatibility of jet fuel with the system materials involves primarily the effect on the systems elastomers, which are designed to swell in the presence of the fuel to seal systems. Although the role of specific compounds has not been well identified, experience has proven that aromatics have a beneficial effect on the elastomers in the system. Therefore a jet fuel with zero aromatics raises concerns over shrinkage of the seals and improper sealing of the system.

Mercaptan Sulfur (D3227) – These compounds are limited because of their odor, adverse effects on certain elastomers and corrosiveness with certain fuel systems materials, particularly cadmium.

Total Acidity (D3242) - Some petroleum products are treated with mineral acid or caustic, or both, as part of refining processes. Any residual acid or caustic is undesirable.

Sulfur (D1266, D2622, D4294, D5453) - Control of sulfur content is important for jet fuels because the sulfur oxides formed during combustion may be corrosive to turbine metal parts or copper or copper base alloys used in various parts of the fuel system. Direct corrosion of metals, especially copper, has been attributed to the presence of hydrogen sulfide or elemental sulfur at levels of 1 ppm or less. Rather than testing for these materials, the copper strip test is performed for jet fuel **(Copper Corrosion Test D130).**

3.1.7 Fuel storage stability

Jet fuel is usually stable when stored in normal conditions because it contains inhibitors to oxidation. However, processes like hydrocracking or high pressure hydrotreating used in refining can destroy the natural oxidation inhibitors in the fuel, so oxidation inhibitors are added to the fuel as early as possible, preferably into the line from the processing unit. The test for **Existent gum (D381, IP540)**, a nonvolatile residue left on evaporation of fuel, is a measurement of the fuel storage stability.

3.1.8 Fuel lubricity

Jet engine fuel systems rely on the fuel itself to lubricate moving parts. However the chemical and physical properties of jet fuel cause it to be a relatively poor lubricant material under high temperature and high load conditions. Furthermore, the deeper conversion processes in the refineries tend to destroy naturally occurring lubricity agents. Due to the nature of their petroleum source, some jet fuels naturally include enough sulfur or nitrogen compounds that act as lubricants. In other fuels, the problem may be corrected by adding lubricity additives, or blending low lubricity fuel with high lubricity fuel. Alternative fuel specification D7566 includes the requirement to test for lubricity (**Lubricity (D5001)** because fuels from bio sources are inherently lower in sulfur compounds than some petroleum-based jet fuels.

3.1.9 Fuel handling

Flash Point (D56) - To minimize the danger of accidental fuel explosions during handling, fuel should have as high a flash point (temperature at which the fuel vapor ignites) as possible, and the specified minimum flash point provides a reference for the maximum temperature at which to handle and store jet fuel to avoid fire hazards. The flash point is also used by local and regional regulations and insurance requirements to determine safe handling and storage practices.

Electrical Conductivity (D2624) - Hydrocarbons are poor conductors of electricity. Charges of static electricity, generated by fuel traveling through the system, may accumulate, and if static electricity dissipates through sparking this can create problems in the handling of aviation fuels. Usually electrical conductivity additives are added to dissipate charge more rapidly.

3.1.10 Fuel cleanliness and contamination

Modern aviation fuel systems require a fuel free of water, dirt and foreign contaminants. As jet fuel moves through the distribution and storage infrastructure, the chances for contamination exist. Therefore, tests have been designed to identify the following contaminants:

Water: Very small traces of free water can adversely affect jet engine and aircraft operation particularly by ice formation. Tests and controls are in place to reduce the risk associated with presence of water or particulate matter. Across the supply chain, the fuel is tested for cleanliness at various points for water and particulate matter contamination.

Microbial Contamination: Microorganisms that have become established in the fuel system can lead to problems such as corrosion, odor, filter plugging, decreased stability, and deterioration of fuel/water separation characteristics. Gross evidence of the presence of microbial contamination can include suspended matter in the fuel or at the fuel water interface and/or smell of rotten eggs, which is due to the presence of hydrogen sulfide. Usually, difficulties can be avoided by good housekeeping techniques, but major incidents in recent years have led to the development of biocides, as well as microbial monitoring tests for jet fuels. Fuel in tropical areas is particularly at risk because elevated fuel temperatures over time favors microbial growth.

Surfactants (D3948): A key element in preventing contamination is to minimize or eliminate surfactants, which can lower the ability of fuel handling systems to remove dirt and water. Surfactants can disperse dirt and water so finely that they pass through filters. They can also adsorb on the surfaces of filters and coalescers and interfere with water removal, and they can also lift rust from surfaces, increasing the amount of solids in the fuel.

3.2 Full conformity test

The set of tests required to confirm that fuel meets all the specifications in ASTM D1655 and D7566 is commonly referred to as a full conformity test. A list of the detailed requirements of the specifications and the approved ASTM test methods are shown in Table 3 and explained in more detail in the remainder of this section. Any of the listed test methods can be used; however, in case of discrepancy in test results, ASTM identifies some of the methods as referee methods to settle disputes.

Table 3: Detailed requirements for full conformity tests of aviation turbine fuels (Extracted from ASTM D1655 and D7566 Table 1; footnotes not included)

Requirement	Specification		ASTM Test Method
	D1655	**D7566***	
COMPOSITION			
Acidity, total mg KOH/g	max 0.10	max 0.10	D3242
1. Aromatics, vol %	max 25	max 25 **min 8**	D1319
2. Aromatics, vol %	max 26.5	min 8.4	D6379
Sulfur, mercaptan,[C] mass %	max 0.003	max 0.003	D3227
Sulfur, total mass %	max 0.30	max 0.30	D1266, D2622, D4294, D5453
VOLATILITY			
Distillation temp, °C			D86**, D2887
T10 (10 % recovered, temp)	max 205	max 205	
T50 (50 % recovered, temp)	report		
T90 (90 % recovered, temp_	report		
T50 – T10		**min 15**	
T90 – T10		**min 40**	
Final boiling point, temp	max 300	max 300	
Distillation residue, %	max 1.5	max 1.5	

Requirement	Specification		ASTM Test Method
Distillation loss, %	max 1.5	max 1.5	
Flash point, °C	min 38	min 38	D56 or D3828
DENSITY	775 to 840	775 to 840	D1298 or D4052
Density at 15°C, kg/m^3	775 to 840	775 to 840	D1298 or D4052
FLUIDITY			
Freezing point, °C max	−40 Jet A	−40 Jet A	D5972, D7153, D7154, D2386**
	−47 Jet A-1	−47 Jet A-1	
Viscosity −20°C, mm^2/s*l*	max 8.0	max 8.0	D445
COMBUSTION			
Net heat of combustion MJ/kg	min 42.8	min 42.8	D4529, D3338, or D4809
One of the following requirements shall be met:			
(1) Smoke point, mm, or	min 25	min 25	D1322
(2) Smoke point, mm, and	min 18	min 18	D1322
Naphtalenes, vol, %	max 3.0	max 3.0	D1840
CORROSION			
Copper strip, 2 h at 100°C	max No. 1	max No. 1	D130
THERMAL STABILITY			
Filter pressure drop, mm Hg	max 25	max 25	D3241
Tube deposits No Peacock or Abnormal Color Deposits	less than 3	less than 3	
CONTAMINANTS			
Existent gum, mg/100 mL	max 7	max 7	D381**, IP 540
Microseparometer, Rating			D3948
Without electrical conductivity additive	min 85	min 85	
With electrical conductivity additive	min 70	min 70	
Electrical conductivity pS/m (with electrical conductivity additive)	max 600	max 600	D2624
Lubricity mm		**0.85**	D5001

*Note: additional requirements in D7566 compared to D1655 are indicated in bold.

** Note: Referee methods in case of disputes.

As indicated in the table above, there are three expanded requirements in D7566 compared to D1655:

- **Aromatics** – For conventional fuel, only a maximum value for aromatics of 25 % by volume is stipulated. This is to ensure proper combustion without smoke, carbon, or soot deposition. There has not been a need to define a minimum aromatic concentration because petroleum-based jet fuel has a significant amount of aromatics, typically between 8 and 22 %. However, some alternative jet fuels do not have aromatics and, therefore, a minimum level of aromatics needs to be specified since aromatics are important for certain engine components such as elastomer seals.

- **Distillation –** Fuels certified to ASTM D7566 specifications have more specific and detailed requirements for distillation \ than conventional jet fuels. This is to ensure a proper and smooth boiling range distribution.

- **Lubricity –** Lubricity is specified for D7566 jet fuel because it is recognized that so far these fuels consist of a mixture of relatively pure hydrocarbons without the polar acids that enhance lubricity. Conventional fuel is a more complex mixture which naturally contains lubricating agents sufficient to ensure the smooth operation of the moving parts in engine fuel systems.

The test methods approved by ASTM to conduct a full conformity test of jet fuel according to the D1655 and D7566 specifications are discussed below. A basic description of the test and required test equipment is also provided. For more details on test descriptions, please visit the ASTM International website: www.astm.org

3.2.1 Composition

Acidity – Test method: ASTM D3242 *Test Method for Acidity in Aviation Turbine Fuel*

A weighed amount of sample is dissolved in titration solvent and titrated colorimetrically with potassium hydroxide. The result, expressed in mg/KOH/g, is the amount of acidity in the fuel.

The test is basic titration and does not need sophisticated equipment (see Figure 1):

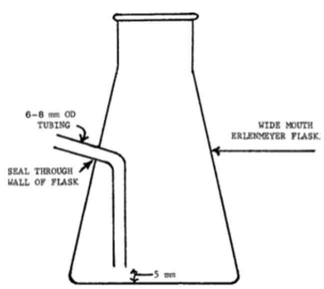

Figure 1: Titration flask for use in test method ASTM D3242 (Source: www.astm.org)

Aromatics – Test method 1: ASTM D 1319- *Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption*

A small amount of sample is placed at the top of a capillary glass adsorption column packed with activated silica gel, after the top layer of the gel has been treated with fluorescent dyes. Isopropyl alcohol or isoamyl alcohol is used to carry the sample and the fluorescent dyes down the column. The hydrocarbons separate into bands of aromatics, olefins, and saturates based on their different affinity for the silica gel. The fluorescent dyes, which also selectively separate, make the boundaries of different type of hydrocarbons visible in UV light.

The test requires a set of adsorption columns with standard wall and precision bore (see Figure 2):

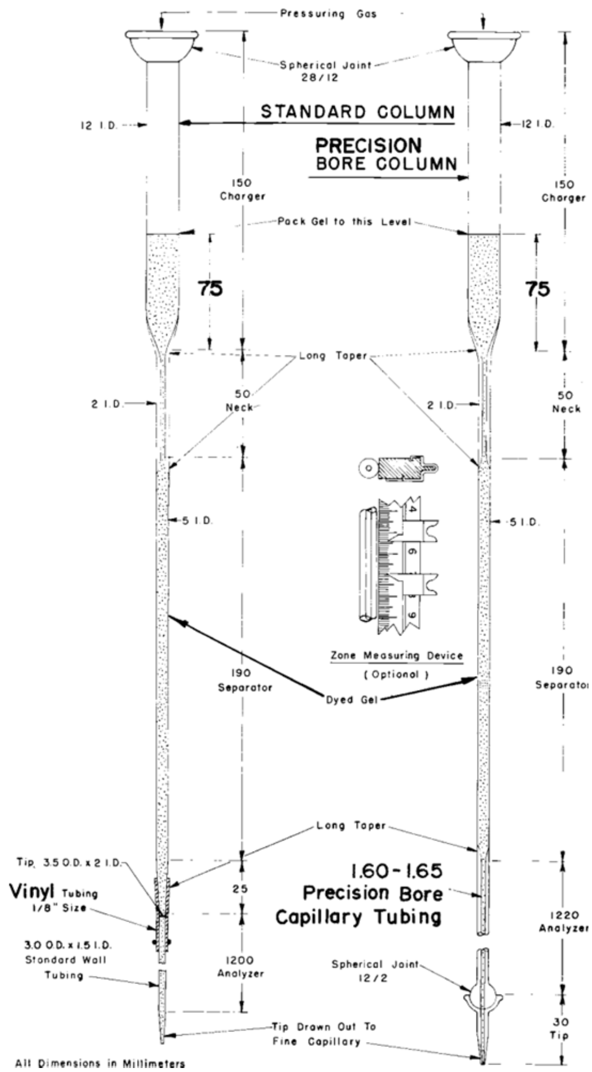

Figure 2: Adsorption Columns with Standard Wall (left) and Precision Bore (right) Tubing in Analyzer Section for use in test method ASTM D1319 (Source: www.astm.org)

Aromatics – Test method 2: ASTM D6379- *Test Method for Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates Using High Performance Liquid Chromatography Method with Refractive Index*

A fixed volume of sample diluted 1:1 with the mobile phase (heptane) is injected into a high performance liquid chromatograph equipped with a polar column. The polar column has strong affinity for aromatic hydrocarbons; therefore the aromatics are separated from the non-aromatics into distinct bands based on their molecular structure. The refractive index detector connected to the column detects the components as they elute from the column. The data processor continually monitors the signals from the detector, compares them with the signals from a previously-run standard in order to calculate the percent of the individual aromatic hydrocarbon-types, which added give the result as total aromatics content.

Mercaptan Sulfur – ASTM D3227: *Test Method for (Thiol Mercaptan) Sulfur in Gasoline, Kerosene, Aviation Turbine Fuel, and Distillate Fuels*

A hydrogen sulfide-free sample is dissolve in alcoholic sodium acetate and potentiometrically titrated with standard silver nitrate solution. This precipitates the mercaptan sulfur as silver mercaptide, and the end point of the titration is indicated by a large change in the titration cell potential. The equipment as described in the procedure consists of any automatic titration system using the required electrode pair, and precision burette.

Note C of Table 1 in ASTM D1655 states that the Mercaptan sulfur determination may be waived if the fuel is considered 'sweet" by the doctor test described in ASTM D4952 (see below).

Active Sulfur Species (Qualitative) ASTM D4952- *Test Method for Qualitative Analysis for Active Sulfur Species in Fuels and Solvents (Doctor Test)*

This is a very simple test Pass/ Failed test, requiring only test tubes and chemicals. A small amount of the sample is vigorously mixed with 5 mililiters (ml) of sodium plumbite solution and then a small amount of pure, sublimed flowers of sulfur. After a few minutes, two layers separate – the fuel on the top and the solution on the bottom – and a pass/fail result (reported as sweet/sour) is assessed based on the changes in color of the sulfur film. The change in color indicates that the reaction of mercaptan and sodium plumbite has occurred, which means mercaptan sulfurs are present in higher concentration than expected.

Sulfur – Test method 1: ASTM D1266 - *Sulfur in Petroleum Products (Lamp Method)*

A sample is burned in a glass lamp with a cotton wick to oxidize the sulfur to sulfur oxide. The combustion gases are bubbled through a solution of hydrogen peroxide to convert the sulfur dioxide to sulfuric acid. The amount of sulfuric acid formed is measured either by barium precipitation or by titration.

The test requires an assembled lamp unit (see Figure 3):

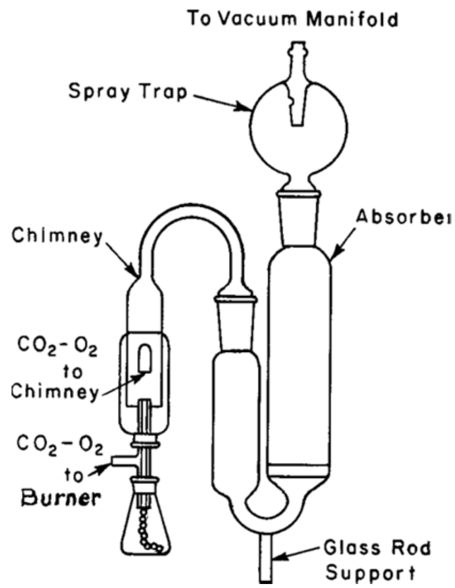

Figure 3: Illustrative Sketch of the Assembled Lamp Unit used in test method ASTM D1266 (Source: www.astm.org)

Sulfur – Test Method 2: ASTM D2622 - *Sulfur in Petroleum Products by X-Ray Spectrometry*

A sample is placed in an X-ray beam and the intensity of the sulfur X-ray fluorescence is measured and used to calculate the sulfur content of the sample. A Wavelength Dispersive X-Ray Fluorescence Spectrometer (WDXRF), equipped for X-ray detection in the wavelength range from about 0.52 nm to about 0.55 nm (specifically at 0.537 nm), is necessary for meeting the requirements specified in the method.

ASTM, under a note in the procedure, acknowledges that the equipment for Test Method D2622 tends to be more expensive than that required for alternative test methods.

Sulfur – Test Method 3: ASTM D4294 - *Standard Test Method for Sulfur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry*

A sample is placed in an X-ray beam and the resultant characteristic X radiation is measured and used to calculate the sulfur content of the sample. The main equipment needed is an energy-dispersive X-ray Fluorescence Analyzer meeting the requirements described in the method.

Sulfur – Test Method 4: ASTM D5453 - *Standard Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence*

A sample is burned to oxidize any sulfur to sulfur dioxide. The combustion gases are irradiated with UV light and the fluorescence of the sulfur dioxide is measured and reported.

The apparatus for this test includes (see Figure 4):

- a furnace held at a temperature of around 1075 degrees C sufficient to pyrolyze all of the sample and oxidize sulfur to sulfur dioxide,
- a quartz combustion tube,
- flow control to maintain a constant supply of oxygen and carrier gas,
- drier tube to remove the water vapor,
- UV Fluorescence Detector capable of measuring light emitted from the fluorescence of SO_2 by UV light,
- refrigerated circulator,
- and a balance.

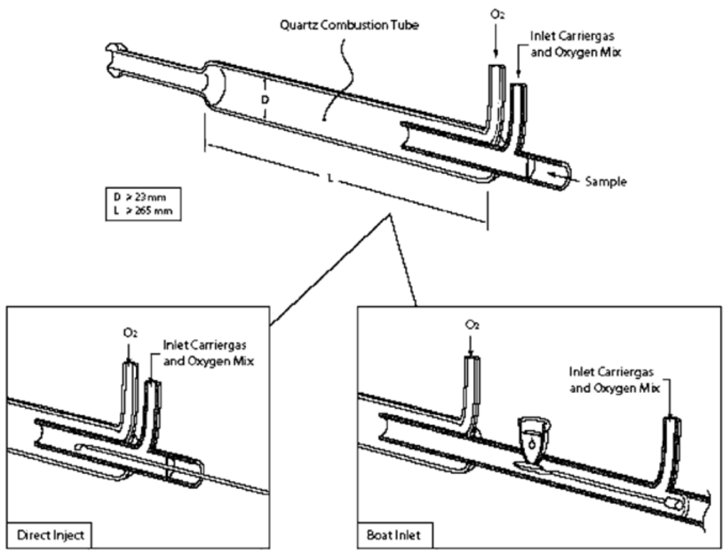

Figure 4: Conventional Combustion Tubes for test method ASTM D5453 (Source: www.astm.org)

3.2.2 Volatility

Distillation – Test method 1: ASTM D86- *Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure*

A 100 ml sample is placed in a round-bottom flask and heated at a rate specified for a sample with its vapor pressure characteristics. Vapor temperatures are recorded when the first drop of condensate is collected (initial boiling point) and at recovered volumes of 5 ml, 10 ml, 15 ml, 20 ml, and every 10 ml interval to 90 ml, 95 ml and at the end of the test (end point). The amount of sample remaining in the flask at the end of the test and the amount lost during the test (both in percent by volume) are recorded and calculated, respectively.

ASTM D86 describes both manual and automatic procedures. A diagram of the apparatus for manual procedures is shown in Figure 5. All automatic equipment has to be approved by ASTM. The prices for the available and approved automated equipment start around $33,000. The automatic procedure requires minimal technician involvement.

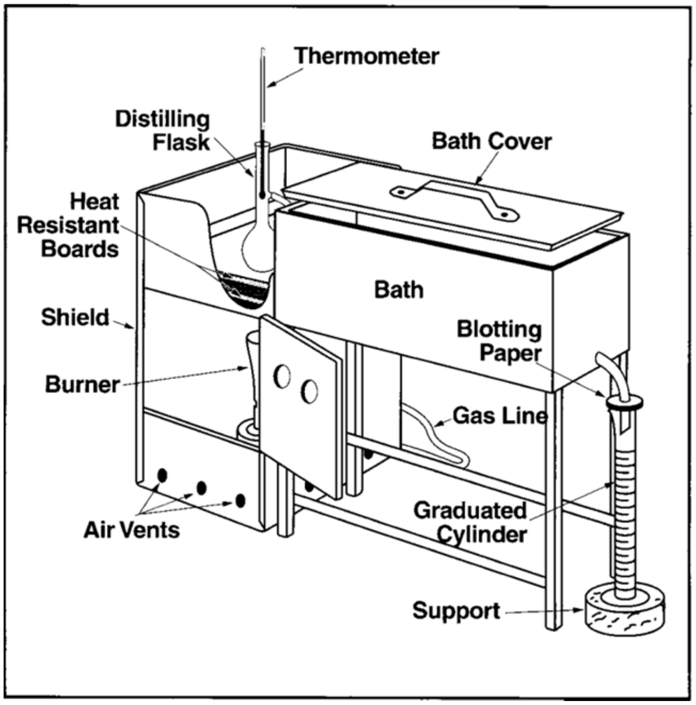

Figure 5: Manual Apparatus Assembly Using Gas Burner for test method ASTM D86 (Source: www.astm.org)

Distillation – Test method 2: ASTM D2887- *Standard Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography*

The boiling range distribution determination by distillation is simulated by the use of gas chromatography. The hydrocarbon components of the sample are extracted in the column in order of increasing boiling point. The column temperature is raised at a reproducible linear rate and the area under the chromatogram is recorded throughout the analysis. Boiling points are assigned from a calibration curve obtained under the same chromatographic conditions by analyzing a known mixture of hydrocarbons. From these data, the boiling, range distribution can be obtained.

The equipment is a gas chromatograph with strictly imposed performance characteristics, specified in the test method.

Flash Point – Test method 1: ASTM D56- *Standard Test Method for Flash Point by Tag Closed Cup Tester*

A sample is placed in a lidded cup and heated at a slow, constant rate. At regular intervals, the lid is opened and an ignition source is directed into the cup. The lowest temperature at which the ignition source causes the vapor above the sample to ignite is the flash point.

ASTM D56 describes the procedures for both manual equipment and automatic equipment. The manual equipment is shown in Figure 6: Tag Closed Flash Tester (Manual) from ASTM D56. Any automatic equipment has to be approved by ASTM. The price of the automatic flash point apparatus (start at over $22,000) is over 10 times that of the manual equipment (about $2,000). For the automatic equipment the only task needed to be performed by a technician is to setup the sample. The equipment does all determinations and corrections.

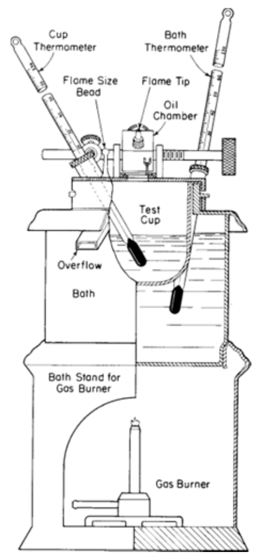

Figure 6: Tag Closed Flash Tester (Manual) from ASTM D56 (Source: www.astm.org)

Flash Point – Test method 2: ASTM D3828- *Standard Test Methods for Flash Point by Small Scale Closed Cup Tester*

This test specification covers two methods. Method A determines whether a product will or will not flash. For this test, a 50 ml sample is introduced, by syringe, into the test cup of the equipment that is set and maintained at a specific temperature. After a specified time, an ignition source is applied to determine if a flash occurred or not. Method B, which determines the flash point of the sample, is a repetition of Method A: the test is repeated with a fresh sample at other fixed temperatures until the flash point is established with the required precision.

D3828 covers both manual and automatic procedures. All automatic equipment has to be approved by ASTM. The price of the automatic equipment is much higher than the manual, starting at around $20,000.

3.2.3 Density

Density – Test Method 1: ASTM D1298- *Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method*

Fuel is transferred to a cylindrical container and an appropriate hydrometer is carefully lowered into the cylinder and allowed to settle. After the temperature of the sample has equilibrated the value on the hydrometer scale is read as instructed in the method and reported. The result must be corrected to 15º C, and can be reported as API gravity, relative density or density in kg/m^3.

Equipment needed: appropriate cylinder, hydrometer, and thermometer.

Density – Test method 2: ASTM D4052- *Standard Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter*

A small volume of a sample is introduced into an oscillating tube held at constant temperature. The change in oscillation frequency caused by the change in the mass of the tube is related to the density of the sample.

The main part of the equipment is the Digital Density Analyzer - a digital analyzer consisting of a U-shaped, oscillating sample tube and a system for electronic excitation, frequency counting, and display. The instrument must be capable of meeting the precision requirements described in the test method.

3.2.4 Fluidity

Freezing point – Test method 1*:* ASTM D2386- *Standard Test Method for Freezing Point of Aviation Fuels*

A sample is placed in a special jacketed tube fitted with a stirring rod and a thermometer. The tube is placed in a low-temperature bath and stirred as the sample cools. When crystals of hydrocarbons appear, the tube is removed from the cooling bath and allowed to warm up slowly with continuous stirring. The temperature at which the hydrocarbon crystals completely disappear is the freezing point.

This manual test is laborious, requires continuous attention and a skilled eye when it comes to the determination of hydrocarbon crystal appearance. D2386 is the reference method in case of dispute.

Freezing point – Test method 2: D5972 *Standard Test Method for Freezing Point of Aviation Fuels (Automatic Phase Transition Method)*

A small portion of fuel is cooled at a constant rate and monitored optically. When the formation of hydrocarbon crystals is detected by the optical system, the sample is then heated at a constant rate until the crystals dissolve. The temperature of the fuel at this point is the freezing point.

A picture of the apparatus for test method ASTM D5972 is shown in Figure 7:

Figure 7: Apparatus Exterior from ASTM D5972 (Source: www.astm.org)

Freezing point – Test Method 3: D7153- *Standard Test Method for Freezing Point of Aviation Fuels (Automatic Laser Method)*

A 10 ml sample is injected with a syringe into the instrument. The sample is cooled at a certain continuous rate while at the same time being illuminated by a laser light source. The specimen is continuously monitored by optical crystal and opacity detectors for the first formation of solid hydrocarbon crystals. When these are detected the sample is warmed at a set rate. The temperature at which the last hydrocarbon crystals return to liquid phase is the freezing point of the sample. The price for the equipment starts around $40,000.

A picture of the apparatus for test method ASTM D7153 is shown in Figure 8:

Figure 8: Automatic Freezing Point Apparatus for test method ASTM D-7153 (Source: www.astm.org)

Freezing point – Test method 4: ASTM D7154- *Standard Test Method for Freezing Point of Aviation Fuels (Automatic Fiber Optical Method)*

A 25 ml of the test specimen is inserted into a test chamber. Then, the sample is cooled while being continuously stirred and monitored by a fiber optical system. When crystal formation is detected, the temperature is recorded and the specimen in the test chamber is warmed, while being continuously stirred and monitored by the optical system, until the crystals in the specimen completely disappear. The temperature of the measured when the last crystals disappear is recorded as the freezing point.

A picture of the apparatus for test method ASTM D7154 is shown in Figure 9:

Figure 9: Automatic Fiber Optical Freezing Point Apparatus for test method ASTM D7154 (Source: www.astm.org)

An ASTM inter-laboratory study was performed to evaluate the ability of freezing point methods to detect jet fuel contamination with diesel fuel. It was determined that the automated methods D5972 and D7153 provide significantly more consistent detection of freeze point changes caused by contamination than test method D2386 and D7154; however, in case of discrepancies, the referee method continues to be the manual method D2386.

Viscosity (at -20 degree C) Test method: ASTM D445- *Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)*

A sample is placed in a calibrated adequate glass viscometer and held at a closely controlled temperature. The time required for a specific volume of the sample to flow through the capillary under gravity is measured. This time is proportional to the kinematic viscosity of the sample.

3.2.5 Combustion

Net Heat of Combustion – Test method 1: ASTM D4529- *Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuel*

The neat heat of combustion of a sample is calculated based on the results of previous tests. These results include the sample's aniline point, density and sulfur content. The aniline point is the minimum temperature at which aniline and petroleum products or hydrocarbon solvents mix completely. It provides an estimate of the aromatic hydrocarbon mixture based on the different values for different hydrocarbon groups: aromatics have the lowest aniline point, paraffins have the highest, and cycloparaffins and olefins have values in between the two classes. The aromatic content is then used to calculate an approximate value for the heat of combustion

Net Heat of Combustion – Test method 2: ASTM D3338- *Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuels*

Similar to test method D4529, the net heat of combustion of a sample is estimated from another set of test results. Here, the results include the sample's API Gravity, aromatics content, and distillation profile.

Net Heat of Combustion – Test method 3: ASTM D4809- *Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)*

A weighed sample of fuel is placed in an oxygen bomb calorimeter under specified conditions. The fuel is ignited and the temperature increase of the calorimeter is used to calculate the heat of combustion.

Smoke Point – Test method: ASTM D1322- *Standard Test Method for Smoke Point of Kerosene and Aviation Turbine Fuel*

A set amount of sample is burned in a wick-fed lamp. The smoke point is the maximum height of flame that can be reached without smoking.

A picture of the equipment for test method ASTM D1322 is shown in Figure 10:

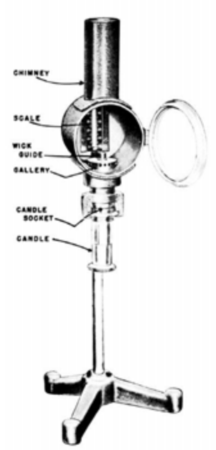

Figure 10: Smoke Point Lamp for test method ASTM D1322 (Source: www.astm.org)

Naphthalene – Test Method: ASTM D1840- *Standard Test Method for Naphthalene Hydrocarbons in Aviation Turbine Fuels by Ultraviolet Spectrophotometry*

A sample is dissolved in iso-octane at a known concentration and the absorbance of the solution at 285 nanometers is measured and used to calculate the naphthalene content.

3.2.6 Corrosion

Direct corrosion of metals by jet fuel, especially copper, has been attributed to the presence of hydrogen sulfide or elemental sulfur at levels of 1 ppm or less. Rather than testing for these materials, the copper strip test is performed for jet fuel.

Copper Strip – Test method: D130- *Standard Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test*

A polished copper strip is immersed in a sample for 2 hours at 100 degrees C and then removed and washed. The result is determined by qualitatively rating the copper surface by comparing it to the standard.

3.2.7 Thermal Stability

Test method: D3241- *Standard Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels*

The instrument replicates the condition in the jet engine: fuel is pumped over a heated aluminum alloy tube at a constant flow rate for 2.5 hours at set temperature (260 degrees C). After contact with the tube, the fuel is filtered to collect any solid decomposition products. The pressure drop across the filter is monitored during the test. At the end of the test, the tube is removed and visually examined and rated by comparing it to a standard color scale. The visual rating and the pressure drop across the filter at the end of the test are reported as a pass/fail test results.

The equipment for this test is massive and the price starts around $75,000.

3.2.8 Contaminants

Existent Gum – Test method: D381- *Standard Test Method for Gum Content in Fuels by Jet Evaporation*

A measured amount of fuel is transferred to a weighed beaker, placed in a heated bath, and evaporated under a flow of steam. The resulting residue is weighed and reported as existent gum. The equipment (steam generator and heated bath) costs a minimum of approximately $20,000.

A picture of the equipment for test method ASTM D381 is shown in Figure 11:

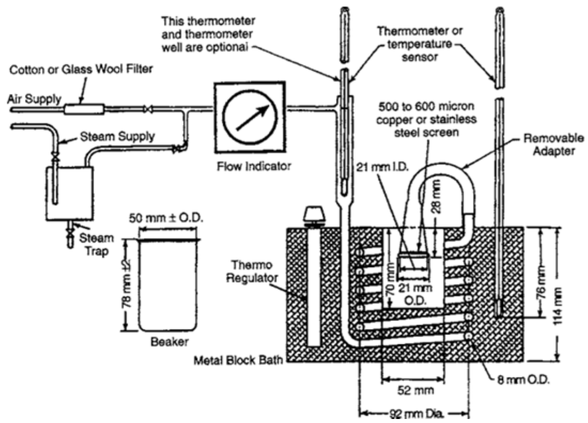

Figure 11: Apparatus for Determining Gum Content by Jet Evaporation for test method ASTM D381 (Source: www.astm.org)

Water Separation Characteristics – Test method: D3948- *Standard Test Method for Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable Separometer*

Using a semi-automatic micro-separometer instrument, a fuel sample is mixed with water, forced through a fiber-glass coalescing medium, and rated. The MSEP rating indicates the relative ease of coalescing water from the sample. The instrument is calibrated with a water free fuel sample. The price for the instrument starts at around $10,000.

Electrical conductivity – Test Method: D2624- *Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuel*

A voltage is applied across two electrodes in the fuel and the resulting current is expressed in terms of the conductivity of the sample. In the case of portable conductivity meters, the current measurement is made immediately, and the instrument display is the reported result.

Lubricity

Test Method: D5001- *Standard Test Method for Measurement of Lubricity of Aviation Turbine Fuels by the Ball-on-Cylinder Lubricity Evaluator (BOCLE)*

In this test, a non-rotating steel ball is held against a cylindrical ring. The cylindrical ring is rotated at a fixed speed while partially immersed in the fuel sample. At the end of the test, the ball is removed and examined for wear. The size of the wear scar (measured in mm) is related to the lubricity of the fuel.

A picture of the equipment for test method ASTM D381 is shown in Figure 12:

Figure 12: Semi-Automatic Ball-on-Cylinder Lubricity Evaluator for test method ASTM D-5001 (Source: www.astm.org)

3.3 Eight-point test

A set of tests that are routinely used in the aviation industry to verify the quality of jet fuel is the so-called eight-point test. Once a batch of certified jet fuel is dispatched from the refinery, it will pass through the control of many different organizations before finally being loaded into an aircraft. Each stage of this delivery process offers the potential for contamination or degradation of the fuel. It is not feasible from a time or cost perspective to do a full conformity test of each batch of fuel at each of these points; however, based on the industry's experience of handling the fuel according to best practices, as few as eight tests can give a quick and reliable indication of the fuel's quality and cleanliness. This set of tests is required by ATA 103 before jet fuel is received at the airport and is referred to in API 1543, as well.

In the eight-point test, test results are compared with previous results that are contained in the batch transfer documents and compared with the applicable standards. At any stage, if any of these tests produces unexpected results, the tested fuel must be quarantined for a full conformity recertification under the original standard.

The tests as required by ATA 103 are listed below. The applicable ASTM test methods are also indicated. Apart from the visual appearance test, descriptions of the test methods have been included in Section 3.

a) Visual appearance in white bucket

   Color limits are not normally a specification item, but color deterioration can be a useful indicator of inter-product contamination or instability (gum formation), or cleanliness of the fuel.

b) Gravity (ASTM D1298 or ASTM D4052)
c) Distillation (ASTM D86)
   - 10%
   - 50%
   - 90%
   - Final boiling point
   - Residue
   - Loss
d) Flash Point (ASTM D56 or D3828)
e) Freezing Point (ASTM D2386, D4305, D5901, D5972)
f) Water Separation Characteristics (ASTM D3948)
g) Copper Corrosion (ASTM D130)
h) Existent Gum (ASTM D381)

3.4 Common testing procedures along the supply chain

Quality control processes in the fuel delivery system are designed to ensure the fuel is safe for aircraft operation. While this process starts at the refinery with the certification that fuel has been produced to meet D1655 or D7566 specifications, the fuel has to meet other requirements on delivery not included in the specification. In their simplest form, those requirements are called "clean and dry" and they ensure the delivery of a fuel free of contaminants that may be picked up in the fuel system anywhere between the point of manufacture until the fuel reaches the aircraft. These requirements are captured in a set of additional procedures including contamination tests and fatty acid methyl ester (FAME) tests. These tests and procedures are discussed below.

3.4.1 Contamination

Jet fuel contaminants can be divided into two broad categories: 1) solid contaminants and water, and 2) other fuels or materials that are soluble in jet fuel. Contamination tests are performed regularly in the industry without being included in the product specification. Some of the procedures that are performed at different points along the distribution system are not part of the specification and they have developed over the years from practical experience in the handling of conventional jet fuel. A recommended source of information on this type of procedures is the ASTM Manual 5, 4th edition: *Aviation Fuel Quality Control Procedures* (ASTM 2010). These tests include:

- Visual appearance is a gross measure of possible contamination with darker or dyed fuel, or solids or free water. Product color can be used for the detection of other petroleum products having darker colors than jet fuel.

- Solid particles are collected on special membrane filters of certain specifications. The solids content can be calculated by weighing the dried membrane or the dirt level can be described by comparing the membrane color to a standard chart.

- Free Water- there are a number of water detection methods ranging from water detecting paste which detects the depth of the water layer in a storage tank, to methods used to detect the suspended free water, usually at a level of 15 or 30 ppm (Shell Detector, Velcon Hydrokit, or Metrocator). The most sensitive method for undissolved water is the Aqua-glo test (ASTM D3240 detects undissolved water down to 2-3ppm. Water content can be also determined by Karl Fisher titration procedure (ASTM D6304).

- Microorganisms – microorganisms must have undissolved free water to grow and reproduce. As a result, most microbial growth is at the fuel-water interface. The products of active microbial growth tend to be corrosive to metal. They can act as surfactants, they from slimes or mats that can plug screeds or filters. There are few tests for determination of microbial contamination such as Hy-Lite kit recommended by IATA.

3.4.2 Fatty Acid Methyl Ester (FAME)

FAME, by nature, is a surface active agent, and theoretically can have an adverse effect on quality control equipment that relies on surface tension to separate water from fuel. Additionally, FAME contamination could cause deterioration in thermal stability resulting in oxidation and release of coke deposits in turbine engines, and could affect the freezing point of the fuel. FAME contamination can be an issue when transporting jet fuel in infrastructure that also transports biodiesel.

FAME is not a component in jet fuel produced from petroleum or via the Fischer Tropsch processes. For HEFA production process, due to the nature of the feedstock, ASTM D7566 Annex 2 specifies that production controls should ensure that the product contains less than 5 ppm of FAME. Two test methods are approved:

Test Method 1: IP 585 *Determination of fatty acid methyl esters (FAME), derived from bio-diesel fuel, in aviation turbine fuel - GC-MS with selective ion monitoring/scan detection method.*

Test Method 2: IP 590 *Determination of fatty acid methyl esters (FAME) in aviation turbine fuel - HPLC evaporative light scattering detector method*

4 Quality Control along the Supply Chain

The collaboration between the entities involved in the jet fuel industry – regulators, equipment manufacturers, fuel producers and handlers, and airlines – has evolved into a complex quality control system governed by best practices and guidelines that ensure robust quality control and safe handling processes. In this section, we more fully describe the responsibilities of the fuel producers and delivery companies.

4.1 Supply Chain Overview

Once a batch of fuel is dispatched from the refinery it passes through the control of many different organizations. It will be transported by pipeline, tanker truck, rail car, or even barge and may be stored in an intermediate storage facility before finally being delivered to the airport. Each of the entities along the supply chain has a responsibility for the ultimate delivery of ‘clean dry’ fuel. Consequently, jet fuel is tested according to each organization’s quality control process at points when it is handed off from one to another. The diagram in Figure 13 provides an overview of the entire jet fuel supply chain and identifies the most common fuel quality control standards that can be applied. Notice that these standards apply whether the fuel is being transported domestically or internationally. Depending on the country, there may be different or additional quality control criteria that need to be followed. International organizations such as IATA, EI, JIG, and A4A have been working diligently for many years to provide as much standardization as possible to simplify quality control procedures.

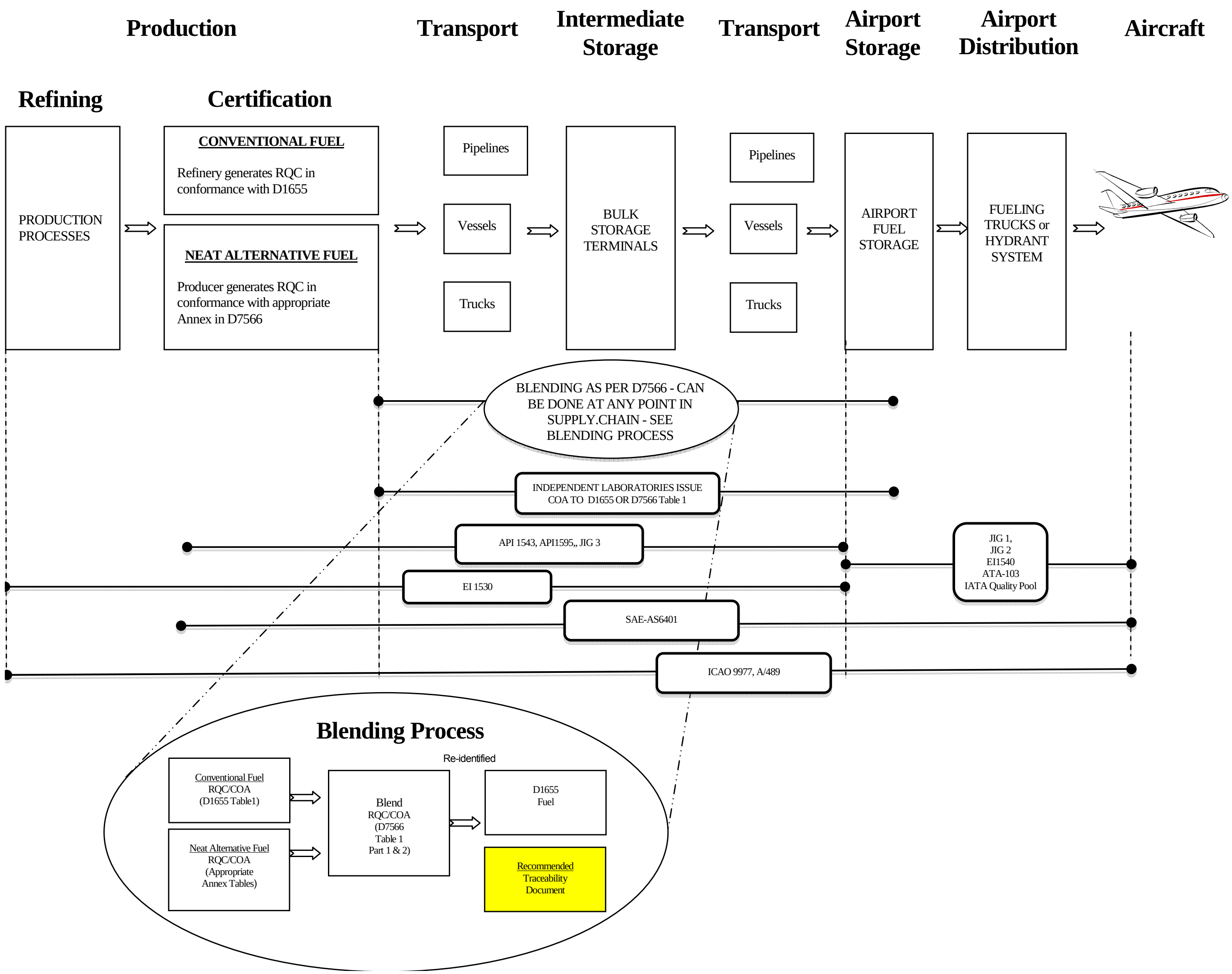

Figure 13: Jet fuel supply chain and quality control process overview

4.2 Refineries

The first step in the fuel quality control process is to certify that the fuel meets the applicable D1655 or D7566 specification. The refinery of origin is responsible for issuing the RQC and for keeping the production records for each unique batch and samples of each batch for a period in case unexpected issues arise downstream. The Certificate of Analysis (COA) is typically issued by an independent laboratory downstream from the point of manufacture. More detail on both documents is given below:

Refinery Quality Certificate: The RQC is the original document describing the quality of the fuel, and determinations of all the properties required in the relevant specifications (ASTM D1655 or D7566). It is prepared by the refinery manufacturing the product and must be signed by an authorized representative. It must include the following:

- Batch number
- Manufacturing refinery
- Documents the fuel specification manufactured against (D1655 or D7566)
- Details of additives used (including content of synthetic components if required by the specification)

Certificate of Analysis: The COA is issued by an independent laboratory after a complete specification analysis of the finished fuel, and is often issued at some point downstream of the point of manufacture. It is dated and signed by an authorized representative of the laboratory and includes the following:

- Batch number
- Manufacturing refinery
- Tested properties required in the relevant specification (D1655 or D7566 and appropriate Annex Tables)
- Need not necessarily contain details of additives used (this is a major difference with respect to an RQC)

Notice that for alternative fuel, the current D7566 specification states that the fuel must be blended up to 50/50 with conventional fuel. Thus, prior to an RQC or COA being generated, the alternative fuel has to be blended. This can occur at the refinery or at any other point in the supply chain. The implications of where the fuel is blended and, thus, certified, will be discussed in Sections 4.2.2 and 5.

Once the certified fuel leaves the point of manufacture or blending, handlers have to follow certain guidelines. EI 1530 applies from the point of manufacture to delivery at the airport. API 1543 and JIG 3 apply from when the fuel leaves the refinery to when it reaches airport storage.

JIG 1+2, ATA 103, or IATA Quality Pool apply once the fuel is received into airport storage and until it gets dispensed into the aircraft tanks.

4.2.1 Refinery batch traceability

During its journey from the refinery to the airport, the traceability of the jet fuel back to its manufacturing origin or the point at which it was last certificated is preferred. To this end, the refinery issues a unique and traceable batch reference number for each production batch and each batch of product is tested and certified as meeting the relevant ASTM specification.

Within the distribution network, batch integrity is maintained, monitored, and rechecked until the fuel is mixed with other fuel either at an intermediate storage facility or at an airport. From that point forward, batch identity is lost and the RQC is no longer applicable and a new COA needs to be generated. Chapter 2 of EI 1530 has detailed information on the types of documents required to accompany the batches on their journey to the airport according to the path traveled (e.g. if they were held in intermediate storage or were delivered directly to the airport). The same chapter in EI 1530 also includes information on the product audit trail necessary at each stage in the supply chain.

4.2.2 Process Control and Management of Change (MoC)

It is of critical importance for refineries to ensure that the fuel is manufactured consistently to meet the requirements in the chosen specification. According to EI 1530, “experience has shown that aircraft fuel-related problems can often be traced back to refinery processing deficiencies” (EI 2012). Therefore, the refining industry has created ways to anticipate and avoid problems related to the manufacture of the fuel. One of these ways consists of process control, i.e. identifying how different refinery processes are more likely to impact fuel properties. For example, Table 4 shows a number of refinery processes and their possible impact on several fuel properties. This type of refinery process to fuel property mapping is useful if the need arises to investigate deviations in certain properties of the finished fuel.

Table 4: Example of possible impacts of refinery processes on fuel properties (Source: Adapted from (EI 2012)).

Refinery process	Sensitive fuel property	Likely cause
Straight-run (untreated)	Mercaptan sulphur, acidity, thermal stability, odor, color	Crude selection
	Water separation properties, conductivity response	Impurities
	Salt content	Carryover from salt dryer due to improper operation or maintenance
Hydrotreatment/ hydrocracking	• Corrosivity (H_2S) • Peroxidation • Thermal stability • Color	• Insufficient steam stripping. • Insufficient or mis-applied antioxidant • Insufficient hydrotreatment of cracked components • Change of catalyst
Wet treatments Caustic wash (including use of sweetening unit without reactor step) Merox™ and similar sweetening units Sulphuric acid	Acid/base number (caustic carryover)	Insufficient water wash
	Water separation properties, color, conductivity response	• Impurities, surfactant formation • Deficiencies in caustic quality • Insufficient water wash • Spent clay treaters
	Salt content	Carryover from salt dryer due to improper operation or maintenance

Note that Table 4 is for refinery processes using conventional petroleum feedstock. As the alternative fuel industry expands and reaches commercial scale, similar process control mappings would be very helpful, especially for new fuel producers.

MoC recognizes that changes in one part of the refining operation or other elements of the supply chain (e.g. feedstock selection, processing steps, additives, blending, storage and handling infrastructure) may have unintended consequences downstream. MoC provides a system to identify, evaluate, authorize, and document changes in a consistent and systematic way to ensure that knowledge is captured and retained and that, ultimately, the quality of the fuel is maintained (EI 2012). EI 1530 has more details and an example review process. MoC will be particularly useful for alternative fuel producers as their production systems and supply chains mature.

Addition of MoC to ASTM D1655 happened in 2003, when ASTM approved to add a refinery MoC requirement. This MoC requirement is intended to control use of refinery processing additives that can potentially affect fuel quality if used improperly, without introducing onerous batch-testing requirements to the specification. The discussion that led to the introduction of the refinery MoC to the specification originated in a recommendation from the Australian Transportation Safety Bureau as an outcome of their investigation of a fuel contamination incident caused by a refinery corrosion inhibitor. Refineries in the US operate under OSHA Process Safety Management regulations that include a MoC requirement. Although the OSHA MoC requirement is directed at safety and health, it is expected that refineries will be able to comply with this proposal by adding a fuel quality element to their existing MoC process. The same language regarding MoC is used in DEF Stan 91-91 and has the same intent.

ASTM D7566 highlights the need for a Management of Change system that evaluates the impact of processing changes in manufacturing the different types of SPKs. Both ASTM D1655 and D7566 recommend that changes in the fuel handling system to be subject of a formal Risk and Management of Change Assessment to ensure product quality is maintain.

4.3 Blending

It is important to note the blending requirement of D7566 for alternative jet fuels. D7566 is based on a blended mix of the synthetic fuel with jet fuel conforming to D1655 with up to a maximum of 50% alternative fuel by volume. This means that the neat alternative fuel produced by the refinery will leave the manufacturing facility with a Quality Document issued against appropriate D7566 Annex Tables (for FT SPK the specification is D7566 Table A1.1 and A1.2, for HEFA SPK the specification is D7566 Tables A2.1 and A2.2), and must be blended with conventional jet fuel before the refinery issues its RQC or a COA against D7566 Table 1, part 1 and 2. In cases where the densities of the neat alternative jet fuel and the conventional blendstock are significantly different, care should be taken to ensure a homogenous blend.

The blending requirement has significant implications for production facilities of alternative jet fuel that do not have access to D1655 certified jet fuel. In that case, certification will need to occur at a blending location outside of the production facility. There, if the fuel does not meet the specification after blending, it will not be allowed to enter the jet fuel supply chain and will have to be quarantined. Based on the parameters that are out of specification, a decision will have to be made to either have the product returned to the production facility, sold as downgraded product, or disposed of in some other manner.

Another question associated with blending is the possibility of “re-blending.” D7566 allows a maximum blend ratio of 50/50 of alternative and conventional fuel. Once the fuel is certified to D7566, it is re-identified as D1655 fuel, and treated as such all throughout the Supply Chain. This means that the blended fuel, since it is now certified to D1655, could be considered blendstock. Thus, theoretically, a 50/50 blend could be re-blended with neat alternative fuel, resulting in a blend with more than 50% alternative fuel. Such eventuality has been anticipated by the D7566 specification. As mentioned earlier, alternative jet fuel has a lower density that conventional jet fuel. One of the reasons behind the 50/50 maximum in D7566 was to avoid re-blending since a blend with more than 50% alternative fuel is not likely to meet the density specification.

4.4 Transportation from the refinery to the airport

It is the responsibility of the final delivery company to furnish on specification, “clean and dry” fuel to an airport. Organizations such as API, EI, and JIG have issued best practices for handling procedures and testing guidelines to help achieve this goal, as discussed in more detail below.

4.4.1 Batch traceability

A significant portion of the jet fuel consumed in the U.S. is delivered by pipeline. Other transportation modes include tanker truck, rail car, and barge. In some of the larger metropolitan areas with several airports using large volumes of jet fuel, pipeline delivery is the only practical method. For example, in the New York metropolitan area, the three major airports (JFK, EWR, and LGA) consume several million gallons of jet fuel daily, all of which is delivered by pipeline.

In general, pipelines deliver a multitude of products (e.g., gasoline, diesel, home heating oil). Therefore, intermediate terminals are situated throughout the nation where several batches of product are stored and accumulated until sufficient demand is available for a large bulk delivery. For the purposes of quality control as defined by API (now Energy Institute, EI) in API 1543, a “batch” is a “distinct quantity of fuel that can be characterized by one set of test results including the type and amount of additives present” (API 2009). Accordingly, all batches of jet fuel leaving a refinery are certified by an RQC that specifies the properties of the fuel; however, once two or more individual batches enter a co-mingled storage facility, their batch identity according to the EI definition is lost. In order to assign a true batch number to a given volume of fuel leaving the co-mingled storage according to the EI definition would require a full conformity test and the issue of a COA. Those tests are more expensive and more time-consuming than the eight-point test currently approved to be performed in the absence of a COA. Therefore, the pipeline industry has developed a batch control and system of traceable codes that are not truly representative of the EI definition of a “batch”. These batch numbers are generated for volumetric accountability and do not carry over the certificate of analysis (COA) that accompanied the individual batches. The fuel leaving the facility is only checked with the eight-point test that does not provide all the information contained in a COA.

4.4.2 Testing along the supply chain

Once a batch of fuel leaves the refinery, its quality is rechecked at different times as it is handed off between different entities. During this time, the quality test lineup is experience-based and can differ from one company to another. Some of the most commonly used tests are:

- Density (D1298 , D4052)
- Distillation (D86, D2887)
- Flash Point (D56, D3828)
- Freezing Point (D2386, D4305, D5901, D5972)
- Existent Gum (D381)
- Copper Corrosion (D130)

- MSEP- Water Separation Characteristics by Portable Separometer (D3948)
- Color (D156)
- Electrical Conductivity (D2624)
- JFTOT- Thermal Oxidation Stability (D3241)

Some of these tests are also part of the set of tests required at a minimum by ATA 103 as part of the fuel check at the airport receipt, in case of a full COA is not available. The results of these tests are compared to expected results, and if the test results are outside the allowable specification limits, the fuel batch has to be segregated and quarantined until further testing has established that the quality is acceptable for aviation use. API 1543 requires that when a quality certificate does not accompany the product received into pre-airfield storage or one is not available, a full conformity test to the relevant fuel specification must be carried out before release. ATA 103 states that when batch traceability is lost during delivery, an eight-point test on receipt at the airport will suffice to test for acceptability.

According to API 1543 recommended practices, a Release Certificate is attached to every fuel transfer which is signed by an authorized person and certifies conformity with applicable specifications. It indicates:

- Time and date
- Product quality
- Batch number
- Density at 15 degrees C
- Service tank number
- Water check

Other recommended practices in API 1543 include:

Re-certification Test Analysis: This is used to check that the quality of the product has not changed and is maintained within tolerated limits. Full re-certification is not always mandatory but it is usually required after the use of non-dedicated transport. If the result of analysis does not match the tolerated difference between the re-certification analysis and the previous analysis, the product it is not used before the cause of the incident has been found and the other specifications match the limits.

Contamination Analysis: This is performed before the offloading of a sea vessel. A re-certification analysis is usually performed in any case at the end of the offloading.

Periodic Test Analysis/ Periodic Test Certificate: The Periodic Test Certificate confirms that the product in stock still matches the major aviation fuel specifications in case the product had been stored for a long period of time.

Visual Checks: These are performed on routine basis at all points during the supply chain. Visual checks are required to check that the product is free of:

- Water
- Sediments /particulate contaminant
- Obvious color bodies and have normal appearance /color

Acceptability Checks: These are performed usually on product receipt and include:

- Visual check, and
- Density measurement (density is compared with the density on the release certificate and the difference cannot surpass a set value)

Particulate Detection Checks: There are two types of checks, including a colorimetric and a gravimetric test. These give an indication on the solid particles content in the fuel. These are performed periodically and show evidence of the effectiveness of the filtration equipment and the validity of quality control procedures. Keeping the tests records provides a history of normal and abnormal filter and/or fuel conditions.

Electrical Conductivity Tests: These are performed at different times of the product life. They give an indication of whether more additives are necessary, or particular precautions should be taken in fuel handling.

4.5 Airport storage and delivery to wing

Once fuel is within an airport, the quality control processes are more systematic than during delivery. Even though each airline is ultimately responsible for the quality of the fuel in its aircraft, in reality it must often rely on an airport's fuel delivery system to ensure product safety. Today, at most airports around the world, fuel delivery is managed by an independent contractor that is responsible for ensuring fuel delivered to an aircraft meets specification. These fuel services companies are responsible for accepting delivery of and testing fuel that has been ordered by airlines, keeping records, and delivering safe clean fuel to an aircraft wing.

In the U.S., the A4A recommends that its members follow the ATA 103 guidelines for fuel handling at airports. ATA 103 designates use of the eight-point test to check on fuel quality at different points during the handling of fuel at the airport. In contrast to API 1543, which establishes more general minimum requirements for fuel handling, ATA 103 includes specific requirements for fuel handling and testing, including equipment, equipment checks, and recordkeeping. Likewise, the procedures specified by JIG are very rigorous and they apply to jointly owned and operated systems. IATA Quality Pool is often used by foreign carriers.

Most U.S. and Canadian airlines reference ATA 103 in their certification manual and ATA 103 standards are contractually included in fuel delivery agreements. However, the ATA 103 standards are not specified in any government regulation. Federal Aviation Regulations reference fuel handling standards when carrying out airline safety inspections and the FAA will check that airlines have systems in place to audit the companies that are handling fuel delivery to ensure fuel is being appropriately tested; however, the FAA does not set the standards for an airport's handling or testing of fuel.

5 Considerations Regarding the Introduction of Alternative Fuels

This section discusses a number of considerations regarding the introduction of alternative fuels into the jet fuel supply chain. While no radical changes to the current quality control system are envisioned, the recommendations herein are meant to strengthen current practices.

5.1 Documentation for neat alternative fuel leaving a refinery

Consideration: This discussion pertains to alternative fuels that need to be blended with conventional fuels to meet the D7566 specification. The need for these fuels to be blended raises the question of the type of documentation that needs to accompany the neat alternative fuel as it leaves the refinery including for export across international borders. The current quality control system is based on the fact that any jet fuel leaving a refinery must be accompanied by an RQC certifying that it meets D1655 or D7566 or an equivalent standard; however, the neat alternative fuels will have to be certified against the appropriate Annex's Tables before the blending can take place.

Recommendation: This gap in the current system could be addressed by issuing a "document of quality" that includes the properties of the neat alternative fuel according to the appropriate annex in the D7566 specification. D7566 recommends the format for this type of document in Annex 4: Form 2 and Form 3. It is strongly recommended to use that format to structure the document of quality, including all the detailed batching and product type info, especially as the industry still gathers data in order to gain more experience in the use of the new type of fuels. This document of quality would become the RQC/COA of the neat alternative fuel. The main reason for blending alternative with conventional jet fuel is to meet the density, lubricity, and aromatics specifications. Knowing these properties for the alternative fuel would allow the blender to select an appropriate blend ratio to ensure the resulting blend meets D7566. For example, the density specification for conventional fuel in D1655 includes a given range. If the density of the blendstock is close to the lighter end of the density spectrum in the specification, the blend with neat alternative fuel may fail the density test because both the blendstock and the alternative fuel may not be dense enough. API 1543, ATA 103, EI 1530, and any other regulations or guidelines would have to be revised to incorporate requirements for batch traceability, certification, quality certification, and documentation for the neat alternative fuels. This "document of quality" can also facilitate and simplify export/import procedures for neat alternative fuels.

5.2 Information on feedstock and production process in RQC and COA

Consideration: When a batch of fuel is dispatched from the refinery into the distribution supply chain, its provenance, which includes the name of the production refinery and details such as any additives, is recorded on its RQC and COA. The current system assumes that all jet fuel is made from petroleum and, therefore, no information on the feedstock or production process is indicated in the RQC or COA. As alternative fuels start to enter the supply chain, it would be prudent to record the feedstock and production process used in the manufacture of all fuels. This information may be relevant for studies related to changes in fuel properties along the supply chain over time, for example.

Recommendation: Include information on feedstock and production process in the RQC and COA of any jet fuel, whether it was produced from petroleum or alternative feedstocks. For alternative fuels certified to D7566, this information should be referenced to the specific annex under which the fuel was certified. Note that this information is already contained in Forms 1, 2, and 3 of Appendix 4 in D7566. Also, for the batch generated after the blending, a traceability document should be issued to accompany the COA of the batch, and it should include information about the origination (feedstock, production process type and original batch numbers) of the blending components. To avoid the use of an extra document to accompany a batch, it is recommended to revise D7566 Annex 4, Form 1 - *Inspection Data on Aviation Turbine Fuel Containing Synthesized Hydrocarbons* to include the detailed information about both the neat alternative fuel and the conventional jet fuel in the blend: original batch numbers, feedstock information, and manufacturers/suppliers. This information is very important, again, as the industry gains experience and needs to build a database on the use of alternative fuels in aviation. Also, the use of this form recommended by ASTM should be strongly encouraged or required in applicable standards throughout the industry. Current standards documents should be revised to make it explicit that aviation jet fuel may be produced from feedstock other than petroleum.

5.3 Additional laboratory tests for D7566 fuels

Consideration: Fuel that is certified under D7566 must meet a specification standard for lubricity which is not part of the specification for D1655. Thus, laboratories that routinely issue COAs for conventional jet fuel may not have the equipment and training required to certify alternative fuels to D7566. This may result in delays and increased cost for fuel handlers if the laboratories they normally use are not in a position to perform fuel-conformity tests to D7566.

Recommendation: The presence of the additional test in D7566 compared to D1655 should be communicated clearly to laboratories that routinely issue COAs for conventional jet fuel. For experienced laboratories that routinely do D1655 tests, the barrier to expanding the capabilities for the extra test should be low.

5.4 Expansion of the Eight-point test

Consideration: As mentioned above, fuel that is certified under D7566 must meet a specification standard for lubricity and minimum levels for aromatics content, in addition to having an expanded distillation specification. These tests are not included in the eight-point test carried out today as defined by ATA 103. Since the eight-point test is a principal means to check the consistency of fuel properties without having to perform a full-conformity test, it would be important for the eight-point test to include lubricity and aromatic content. In addition, there may be other properties of interest, such as sulfur content, that could captured with an expanded eight-point test.

Recommendation: Expand the eight-point test as described by ATA 103 to include tests for lubricity, aromatics, and other properties of interest, such as sulfur content. In addition, replace the current distillation specification to the expanded version in D7566. Furthermore, it would be beneficial to include information such as feedstock and production method as part of product information that accompanies the documentation with results from the eight-point test.

5.5 Blend analysis

Consideration: In order to estimate and monitor the potential impact of the introduction of alternative fuels into the jet fuel supply chain, it is necessary to determine how much alternative fuel is present in each test sample. Unless this datum is present for each fuel sample, it will be impossible to attribute any changing characteristics in the jet fuel supply chain to the presence of alternative fuel. The recommendation above that the RQC and COA include the feedstock and production process for each fuel is only partially effective at capturing this information along the supply chain. As it has been explained, batch traceability is impossible under the current system as batch identity is lost as the fuel enters comingle storage.

An effective means to identify the presence of alternative fuel in a fuel sample is not a straightforward proposition at this time. Because the molecular constituents of alternative fuel vary only slightly from petroleum-based fuel and, moreover, the chemical makeup of petroleum fuels differs depending on the oil source, the presence of any particular molecule in a sample cannot indicate definitively whether it contains alternative fuel.

An approach to detect the presence of fuel made from biomass feedstock is to measure the relative amounts of different isotopes of carbon in the sample, as discussed below; however this method will not work for alternative fuel made from fossil feedstocks, whether coal, natural gas, or from CO_2 captured from industrial processes. For FT fuels, tests based on mid-infrared spectroscopy may be effective in determining the presence of alternative fuel.

Radiocarbon Analysis

There are the three naturally occurring isotopes of carbon: carbon-12 which comprises 99% of carbon in the atmosphere, carbon-13 which represents about 1 %, and carbon-14 which is radioactive and occurs in trace amounts in the atmosphere, about 1 part per billion (ppb).

Carbon-14, which has a half-life of 5,730 years, is constantly produced by cosmic rays in the upper layer of the atmosphere. From there it migrates into the lower atmosphere at a relatively constant rate, where it forms CO_2. CO_2 is the building block of biomass, and as long as they are alive, organisms incorporate carbon-14 into their structure in the same proportion that it is in the atmosphere. Upon death, the carbon-14 content of organisms slowly drops as carbon-14 decays into nitrogen. Radioactive decay occurs at a constant rate which means that the proportion of carbon-14 in a carbon sample can be used to determine its approximate age. Since the half-life of carbon-14 is around 5,730 years, all fossil fuel resources such as coal, crude oil, and natural gas, which are produced from organisms that died millions of years ago, no longer contains any C14. Based on this, the proportion of carbon-14 in a fuel sample can be used to indicate how much of the fuel is derived from biomass (high carbon-14 content) and how much from fossil (zero carbon-14) sources. This principle is used in the determination of the carbon-footprint in discharged carbon dioxide and how much renewable ethanol is contained in gasoline required by the Energy Policy Act of 2005. ASTM has a test method for radiocarbon:

Test method: ASTM D-6866 - *Standard Test Methods for Determining the Biobased Content of Solid Liquid, and Gaseous Samples using Radiocarbon Analysis*

Carbon-14/Carbon-12 and Carbon-13/Carbon-12 isotopic ratios are measured using accelerator mass spectrometry. The method requires modern, sophisticated equipment and results have to be carefully reviewed and interpreted, corrections made for background radiation and "the post-1950 bomb injection of Carbon-14 into the atmosphere" (ASTM D6866). One of the difficulties with this test is that some of the biobased products contain substantial amounts of inorganic carbonates. When preparing the samples for analysis, some or all of the carbon in the inorganic carbonates can be mixed into the samples to be analyzed and this can lead to incorrect results. For example, the USDA definition of "biobased content" requires the determination to be done only on organic carbon. D6866 describes the additional steps necessary to eliminate the errors in the results caused by the inorganic carbonates.

Mid-Infrared Spectroscopy

Another method for determining how much alternative fuel is in a sample is currently being researched by ASTM (ASTM 2010). This method uses a variable filter array infrared (IR) spectrometer. The instrument, a portable mid-infrared spectrometer, was chosen for its resolution and also because of its low cost and portability makes it a promising candidate for on-site testing of jet fuels. The method is currently being tested on blends of conventional jet fuel and FT alternative fuel, specifically a synthetic fuel made by the South African manufacturer Sasol.

The approach is based on the fact that the Sasol fuel showed significant differences in spectral absorbance from conventional jet fuel in two areas within the infrared range. Alternative jet fuel is highly isomerized (i.e., it contains molecules of the same chemical composition but arranged differently) and is likely to have more branching in its hydrocarbons chains than conventional jet fuel. More branching in the fuel means that it will have relatively more CH_3 bonds (one at the end of each branch) than conventional fuel. This correlates with the fact that the main differences in infrared absorbance between the fuels was at the range thought to occur within CH_3 bonds. Further testing is required to determine if alternative fuel made through other FT processes and from other feedstock will also have significant variations in the IR spectrum, and to evaluate whether the approach is applicable to HEFA process fuels.

Recommendation: The ability to monitor the amount of alternative fuel in a jet fuel sample through testing is currently limited. While radiocarbon testing could be used to identify the presence of bio-derived alternative fuel, it cannot reveal the presence of FT fuels made from fossil, non-petroleum-based feedstock. Mid-infrared spectroscopy could be used to identify FT fuels and perhaps other types of fuel, as well. Developments in these areas should be monitored closely with the goal of choosing one or a series of tests that could identify the presence of alternative fuels.

5.6 Improved batch tracking

Consideration: As mentioned above, the current system of batch tracking makes it virtually impossible to identify the manufacturing location of a specific sample of fuel once it enters a co-mingled storage or fuel handling facility. This system has worked well because all jet fuel currently in the system is made out of petroleum; however, as alternative fuels are introduced into the supply chain, knowing the feedstock and production process of each fuel is necessary to monitor changes in fuel properties over time that may occur because of the presence of alternative fuels.

Recommendation: It is worth it to re-think the current system of batch traceability and to propose improvements based on the widespread availability of information management systems. Even though batch identity may be lost as fuel enters a co-mingled storage system, it should be possible to at least keep track of where the fuel came from originally and trace it back to individual refineries, feedstock, and production processes. This is an area that requires further research. As discussed earlier, after blending, the COA should be accompanied by a document describing the origination of the blend components.

5.7 Management of change

Consideration: As stated in Section 4.2.2, a Management of Change (MoC) evaluation is highly recommended whenever changes are introduced in the process to produce, transport, and handle jet fuel to ensure that the fuel remains fit-for-purpose. This applies to changes in a number of elements such as feedstock, processing steps, additives, blending, storage and handling infrastructure. The purpose of MoC is also to make all stakeholders aware that change in one area of the supply chain may have unintended consequences in other areas. MoC provides a system to identify, evaluate, authorize, and document changes in a consistent and systematic way to ensure that knowledge is captured and retained. This would be of great help to the industry as it gains experience with alternative aviation fuels.

Recommendation: It would be very beneficial to develop more specific MOC guidance specifically for D7566 in recognition of the potential lack of experience of new producers. This guidance could be tailored to these new and novel processes of producing synthetic jet fuel. EI 1530 has an extensive section on MoC (Section 3 – Management of Change/New Processes). At a minimum, a reference in D7566 to that particular section could be very helpful to new producers. Furthermore, encourage alternative fuel producers to institute MoC practices and to collaborate with other stakeholders along the supply chain to ensure communication flows and information exchanges whenever changes to the production or handling of fuels occur.

5.8 Compliance with guidelines and regulatory requirements

Consideration: There are a multitude of guidelines covering the supply chain: EI/API/ IATA/ ATA 103/ JIG/ SAE. It becomes very important, if not an issue, to identify which ones a company must take into consideration and adhere to fulfill its contractual obligation with its clients and other stakeholders.

Recommendation: Similar to the previous comment, it would be very beneficial to develop more specific guidance targeted at new producers that narrows down the important elements that new entrants should be aware of. For example, experience with previous airline initiatives has shown that thorough planning, training of all personnel, scheduling, and tight batch quality control contributed to gaining the trust of the stakeholders and in completing successful projects. Our team strongly recommends new producers that bring products to the market should consider having available detailed documentation regarding:

- Feedstock origin
- Sustainable jet fuel production
- Facts & figures, volumes, CO_2, emissions, savings and costs
- Material Safety Data Sheets (MSDS), NFPA codes, or any other regulatory codes.
- Clear supply chain flow. If supplying to end users consider: blending and storage, analysis and certification, transport, transfers, fueling and flight.
- Batches traceability reports, or as recommended earlier the use of D7566 and/or D1655 forms for reporting the inspection results to include all batch info regarding feedstock, type of process, manufacturer, etc.

Also new producers and/or suppliers should plan ahead for Analysis and Certification. For example, some of the tests are not readily available or require extensive turnaround for results.

It is important to remember that every situation is different; each airport and airline have different issues and opportunities, therefore collaboration and clear communication must take place between the parties involved to rule out any confusion and avoid any possible bottlenecks in the process.

6 Fuel Properties Catalog

The characteristics of conventional jet fuel show a natural variability that is driven by different factors, including the type of petroleum (e.g., “heavy” or “sweet”) and refining process used to manufacture the fuel. To address this variability, current standards such as D1655 allow for a range of values for the different properties required in the specification. As non-petroleum fuels are introduced into the jet fuel supply chain, the aviation community would like to understand how the characteristics of the entire jet fuel supply pool may change over time. This would allow expert organizations, such as ASTM, to assess the adequacy of current specifications to anticipate the possible variability in jet fuel properties.

In the U.S., there is currently no consistent and widespread system for measuring and documenting the characteristics of jet fuel in storage at airports. Fuel service companies at an airport test batches of fuel as it is being delivered and sample fuel in storage tanks on a regular basis. The laboratories doing the tests record the results using diverse data collection software packages and report results back to the airports. This test data is retained for a certain time by the fuel service companies, in case of any fuel-related incidents and for auditing purposes, but we are not aware of any fuel service companies that monitor such test results over time.

This section presents an overview of a fuel properties catalog. This catalog is intended to capture the characteristics of the fuel pool as alternative fuels start being introduced; however, given the lack of such a comprehensive catalog for conventional jet fuel today, the catalog could also be useful for keeping track of conventional jet fuel properties even in the absence of significant amounts of alternative jet fuel.

As of the date of this updated report, a prototype fuel properties catalog was developed and implemented by the research team. Observations from implementation of the catalog are also discussed in the sections that follow.

6.1 What data to collect

In order to lower the barriers for implementation, it is recommended that data collection for the fuel properties catalog takes advantage of existing data to the extent possible. Two sets of data regarding jet fuel properties that are collected on a regular basis include the eight-point test and full-conformity tests. Jet fuel quality control tests can be expensive and, therefore, it is better not to require additional tests. For reference, a full conformity test costs between $1,000 and $2,000 and an eight-point test costs between $100 and $200.

The advantages and disadvantages of each test as a source of data for the catalog are discussed below:

Eight-point Test

As described elsewhere, airport fuel system operating companies regularly perform eight-point tests on fuel in their fuel tanks as part of their quality control process. Based on industry experience, it has been established that this set of data is sufficient to determine if the fuel is fit for purpose and its quality has not been altered since it was certified as meeting D1655 specifications; however, to ensure that the test samples are representative of fuel in airport storage tanks, only eight-point test results from tank tests should be collected, not those of incoming batches that are tested prior to acceptance.

The eight-point test results should be widely available, and monitoring these results over time would permit identification of variability trends. Furthermore, since these tests are performed very often, there would be a large amount of test samples to feed the catalog. A disadvantage of using the eight-point test is that it currently does not capture some of the key properties of interest to the jet fuel quality control community, such as aromatics content, distillation, net heat of combustion, and lubricity.

Full Conformity Test Data

An alternative to collecting eight-point test results is to collect full conformity test data. This would already contain the additional data on aromatics, distillation and lubricity that we recognize is missing from the eight-point test; however, full conformity tests are not conducted at all airports as part of quality control procedures. Some airports run these tests on random tanks once or a few times a week. Otherwise, they are usually only conducted on fuel that does not pass the eight-point test or at testing laboratories that issue COAs for batches of fuel on dispatch from refineries. Thus, the amount of data samples available would be far less than if the eight-point test is used.

Volume Data

Another piece of information that is desirable to collect is volume associated with each batch. This is to allow the calculation of volume-weighted averages of the different fuel properties for the combined fuel pool after batches are combined.

Recommendation for data to be collected

The research team recommends a dual approach for data collection. In the long term, the “expanded” eight-point test data that includes information on aromatics, distillation, lubricity, feedstock, production process, and blend level, if possible, should be enough for the purposes of the catalog. In the short term, while the expanded eight-point test is approved and implemented, the recommendation is to collect both the eight-point and full-conformity test data. While this may be cumbersome at first, this is the most practical approach to obtain significant number of test samples and the required information regarding aromatics, distillation, and lubricity. Furthermore, collecting both test data samples will allow a direct comparison that may, over time, indicate which one would be preferred. In addition to the eight-point test and full conformity data, basic information regarding fuel manufacturer, feedstock, and process should also be collected. Volume information specific to each batch represented in the eight-point or full-conformity test should also be collected.

Observations from implementation of the catalog

Through collaboration with a major U.S. airline, the research team was able to obtain information on conventional jet fuel properties for a number of U.S. airports. The type of data obtained changed from location to location, reflecting the variety of data collection in practice today. For most airports, COAs were available although, in some cases, eight-point tests were provided, as well. Batch volume information was not as easy to obtain but was provided in some cases by the FBO.

With respect to alternative fuels, results for only one test sample were obtained. The data was provided by another contractor in a different component of this BAA. An effort was made to collect test results on alternative jet fuel from other vendors and organizations; however, our requests were declined.

6.2 Where and from whom to collect data

There are a number of places along the supply chain where quality control test data could be collected. This implies that there could also be a large number of potential entities that would need to be engaged to collect the data. Possible data collection points are discussed below:

At the Airport

If the intent of the catalog is to monitor the variability jet fuel that is consumed on aircraft, the best place to gather the required data would be at the airport. At most airports in the U.S., jet fuel storage is comingled and, therefore, jet fuel from different manufacturers and points of origin gets combined and mixed together at the airport fuel farm. Therefore, collecting the fuel property data at the airport would give the best possible representation of the jet fuel being consumed.

The collection of fuel quality data at the airport should be fairly straightforward. As mentioned above, this information, in particular results from eight-point tests, is routinely gathered and archived as part of the quality control process of fuel service companies managing airport storage tanks. Furthermore, since at many airports fuel storage is typically managed by one company and sometimes two or three, identifying these companies would not be difficult. Finally, since these companies are hired directly by the airlines or the airports, and assuming the airlines and airports support the creation of the catalog, obtaining the support of these third-party companies should not be difficult.

Other points in the supply chain

As one moves upstream from the airport along the supply chain, it is more difficult to identify the best location to gather the fuel properties information for the catalog. As discussed above, fuel batches travel by different modes and may be co-mingled with other batches at different points in their journey from the refinery to the airport. Moreover, as the fuel moves along the supply chain, it changes custody multiple times and it may be difficult to identify the parties responsible for providing the test data.

At the refinery or blending location

Another possible location to collect fuel property data is at the refinery or blending location in the case of alternative fuels that require blending. Since an RQC or COA is required before the fuel can leave the refinery or blending location, the required information is generated and should be available, in theory. To collect this data, it would be necessary to request the collaboration of refiners and blenders.

Recommendation for where to collect the data

The research team recommends to collect the fuel property data at the airport fuel farm and, if possible, from refineries and blenders willing to participate. Collecting the data at the airport makes the most sense in terms of obtaining an accurate picture of the properties of the fuel pool being used on aircraft. In addition, existing quality control practices and the relatively small number of companies should make the data collection at the airport straightforward. With respect to refineries and blenders, while this data would be very useful, it is unclear how many of these organizations would be willing to cooperate with the catalog; however, an effort should be made to identify and contact them.

Prior to collecting the data, it will be necessary to identify the scope of the data collection effort in terms of number of locations and number of samples per time period (e.g., per week, per month) to ensure it is cost-effective. It is recommended to start with a small number of locations to test the process and then to expand it as more experience is gained.

Observations from implementation of the catalog

The data for the catalog on conventional jet fuel was collected essentially at the airport. In most cases, it was obtained directly from the fuel farm operator. In one case, it was provided by the testing laboratory performing the tests for the fuel farm operator. In another case, it was provided by the fuel supplier for fuel that was being held in storage just outside the airport. In all cases, the data collection of conventional fuel properties was made possible at the request of a major U.S. airline that collaborated with the research team. In the case of the one test result obtained for the alternative fuel, this was provided by the fixed-base operator (FBO) handling the fuel at the airport. This data was obtained through the assistance of the FAA.

6.3 How to collect the data

Producers, inspection companies, laboratories, airports, and airlines use computer systems to input the results of quality control tests and generate analysis reports. These tasks can be accomplished using simple spreadsheets or using more elaborated databases with multiple interfaces, e.g., gathering the results directly from the testing instruments. Specifications can also be built into the system and linked to the type of testing required, so that when a result is entered, the system compares it with the specification and flags it if is outside specification.

There are many custom systems on the market. For example, Nobil Petroleum Testing uses a proprietary software package engineered specifically for inspection companies and petroleum testing laboratories. It is structured based on the D1655 recommended format for reporting inspection data on aviation turbine fuels (see Figure 14). The form incorporates the requirements of the most common international specifications and IATA Guidance Material on Microbiological Contamination in Aircraft Fuel Tanks.

INSPECTION DATA ON AVIATION TURBINE FUEL
(Items in **bold** type are referenced in the specification)

MANUFACTURER/SUPPLIER ______________________
PRODUCT CODE/GRADE______________________
SPECIFICATION______________________
SAMPLE NUMBER______________________
DATE SAMPLED______________________
SAMPLING LOCATION______________________
BATCH NO.______________________
QUANTITY LITRES @ 15°C______________________
QUANTITY U.S. GALLONS @ 60°F______________________
LABORATORY______________________

DATE SAMPLED______________________
DATE RECEIVED AT LAB______________________
CONTRACT NO.______________________
ORDER NO.______________________
TANK NO.______________________
DESTINATION______________________
CRUDE SOURCE______________________
PROCESSING METHOD______________________
REMARKS______________________

Method			Result
		APPEARANCE	
010	D 156	Color (Saybolt)	◊◊◊
020	D 6045	Color (Saybolt)	◊◊◊
030	D 4176	Visual ("Pass" or "Fail")	◊◊◊◊
		COMPOSITION	
100C	**D 3242**	**Acidity, Total (mgKOH/g)**	◊●◊◊◊
110	**D 1319**	**Aromatics (vol %)**	◊◊●◊
112	**D 6379**	**Aromatics (vol %)**	◊◊●◊
115	D 1319	Olefins (vol %)	◊●◊
120	**D 1840**	**Naphthalene (vol %)**	◊●◊◊
130	**D 3227**	**Sulfur, Mercaptan (mass %)**	◊●◊◊◊◊
140	D 4952	Doctor Test (P = pos, N = neg)	◊
150A	D 129	Sulfur, Total (mass %)	◊●◊◊
150B	**D 1266**	**Sulfur, Total (mass %)**	◊●◊◊
150D	**D 2622**	**Sulfur, Total (mass %)**	◊●◊◊
150E	D 3120	Sulfur, Total (ppm)	◊◊◊◊
150F	**D 4294**	**Sulfur, Total (mass %)**	◊●◊◊
150G	**D 5453**	**Sulfur, Total (ppm)**	◊◊◊◊
160A	D 3343	Hydrogen Content (mass %)	◊◊●◊◊
160B	D 3701	Hydrogen Content (mass %)	◊◊●◊◊
		VOLATILITY	
200A	**D 86**	**Distillation by Auto/Manual (°C)**	◊
200B	D 2887	Distillation by GC (°C)	◊
201		Distillation by Initial BP (°C)	◊◊◊●◊
202		Distillation by 10 % Rec (°C)	◊◊◊●◊
203		Distillation by 20 % Rec (°C)	◊◊◊●◊
204		Distillation by 50 % Rec (°C)	◊◊◊●◊
205		Distillation by 90 % Rec (°C)	◊◊◊●◊
206		Distillation by 95 % Rec (°C)	◊◊◊●◊
211		Distillation by Final BP (°C)	◊◊◊●◊
213		Residue (vol %)	◊●◊
214		Loss (vol %)	◊●◊
220A	**D 56**	**Flash Point, Tag Closed (°C)**	◊◊●◊
220B	D 93	Flash Point, PM Closed (°C)	◊◊●◊
220C	**D 3828**	**Flash Point, Setaflash (°C), Meth A**	◊◊●◊
220D	D 3828	Flash Point, Setaflash (°C), Meth B	◊◊●◊
221	D 3828	Flash Point, Setaflash (Flash/No Flash)	◊
230A	**D 1298**	**Density @ 15°C (kg/m^3)**	◊◊◊●◊
230B	**D 4052**	**Density @ 15°C (kg/m^3)**	◊◊◊●◊
231A	D 1298	API Gravity @ 60°F	◊◊●◊
240A	D 323	Vapor Pressure, Reid (kPa)	◊◊●◊
240B	D 4953	Vapor Pressure, Dry Method (kPa)	◊◊●◊
240C	D 5190	Vapor Pressure, Automatic Method (kPa)	◊◊●◊
240D	D 5191	Vapor Pressure, Mini Method (kPa)	◊◊●◊
		FLUIDITY	
300A	**D 2386**	**Freezing Point (°C)**	-◊◊●◊◊
300B	**D 5901**	**Freezing Point (°C)**	-◊◊●◊◊
300C	**D 5972**	**Freezing Point (°C)**	-◊◊●◊◊
300D	**D 4305**	**Freezing Point (°C)**	-◊◊●◊◊
300F	**D 7154**	**Freezing Point (°C)**	-◊◊●◊◊
310	**D 445**	**Viscosity @ -20°C (mm^2/s)**	◊◊●◊◊◊
311	D 445	Viscosity at other temp (mm^2/s)	◊◊●◊◊◊
312	D 445	Temp (°C) of Item 311	◊◊◊◊

Method			Result
		COMBUSTION	
400A	D 240	Net Heat of Combustion (MJ/kg)	◊◊●◊◊◊
400B	D 1405	Net Heat of Combustion (MJ/kg)	◊◊●◊◊◊
400C	**D 3338**	**Net Heat of Combustion (MJ/kg)**	◊◊●◊◊◊
400D	**D 4529**	**Net Heat of Combustion (MJ/kg)**	◊◊●◊◊◊
400E	**D 4809**	**Net Heat of Combustion (MJ/kg)**	◊◊●◊◊◊
410	**D 1740**	**Luminometer No.**	◊◊
420	**D 1322**	**Smoke Point (mm)**	◊◊●◊
		CORROSION	
500	**D 130**	**Copper Strip**	◊◊
510	IP 227	Silver Strip	◊
		STABILITY	
601A	**D 3241**	**Filter ΔP (mm Hg) @ other temp**	◊◊●◊
602A	**D 3241**	**Tube Deposit @ other temp**	◊◊◊◊
603A	**D 3241**	**TDR Spun Rating @ other temp**	◊◊
604A		**Temperature (°C) of above**	◊◊◊◊
601B	**D 3241**	**Filter ΔP (mm Hg) @ 260°C**	◊◊●◊
602B	**D 3241**	**Tube Deposit Rating @ 260°C**	◊◊◊◊
603B	**D 3241**	**TDR Spun Rating @ 260°C**	◊◊
		CONTAMINANTS	
700	IP 225	Copper Content (mg/kg)	◊●◊◊
710	**D 381**	**Existent Gum (mg/100 mL)**	◊◊◊
710A	**IP 540**	**Existent Gum (mg/100 mL)**	◊◊◊
720A	D 2276	Particulate (mg/L)	◊●◊◊
720B	D 5452	Particulate (mg/L)	◊●◊◊
730		Filtration time (minutes)	◊◊
740	**D 1094**	**Water Reaction Interferance Rating**	◊◊
750	D 3948	MSEP (With SDA)	◊◊◊
751	D 3948	MSEP (Without SDA)	◊◊◊

		ADDITIVES	Brand	
800		Antioxidant (mg/L)	[ ]	◊◊●◊
810		Metal Deactivator (mg/L)	[ ]	◊●◊
820		Static Dissipator Additive (mg/L)	[ ]	◊●◊
830A	(D5006)	FSII (vol%)	[ ]	◊●◊◊◊
830B	(FTM5327)	FSII (vol%)	[ ]	◊●◊◊◊
830C	(FTM5340)	FSII (vol%)	[ ]	◊●◊◊◊
840		Corrosion Inhibitor (mg/L)	[ ]	◊◊●◊

		OTHER TESTS	
900	**D 2624**	**Conductivity (pS/m)**	◊◊◊◊
901	**D 2624**	**Conductivity Test Temperature (°C)**	◊◊◊

Comments and/or Additional Tests:
____
____
____
____
____
____
____
CERTIFIED BY ______________________

Figure 14: Form for reporting inspection data on aviation turbine fuels, pp 12 to 15. Source: ASTM D1655 (2011).

Recommendation for how to collect the data

Efficient routine collection of fuel test results will require the design and ongoing management of a computer-based reporting system, and the development of tools to analyze the accumulated data. Even in these times of inexpensive data storage, the more data that is collected, the higher storage fees will be. The research team recommends a two-step approach for implementing the catalog:

- *Step 1: Demonstration catalog* – For the initial version of the catalog, the team recommends to use a system similar to the one used currently by Nobil Petroleum Testing. This system is field-tested and can be modified to capture the additional properties indicated in the expanded eight-point test. Initially, we anticipate that test results will be provided on a voluntary basis, either from fuel service companies or directly from testing laboratories. We will need to discuss what formats will be appropriate with the providers based on their individual test reporting procedures, and may have to develop simple software solutions to accommodate material in different formats.

- *Step 2: Long-term catalog* – Further recommendations regarding long-term collection and compilation of a broad sample of fuel characteristics will be based on experience gained in compiling the demonstration catalog for twelve months. The initial period will allow the team to obtain a better understanding with the practical challenges of collecting, storing, and analyzing fuel test data from many providers across the country.

Observations from implementation of the catalog

A number of lessons learned from the catalog implemented in this project with respect to data collection and recommendations for a long-term catalog are presented below:

- **Test results and data format:** The research team received the data in one of two ways, either electronically as a .pdf file or by fax (in the case of one airport, a research team member could access the data through their automated computer systems). Thus, in the majority of cases, the data in the catalog had to be input manually into the spreadsheet-based catalog. For the purposes of this project, manual input of the data was manageable because we were only receiving data from a number of airports; however, to establish a more comprehensive catalog, it will be important to coordinate with data suppliers to obtain the data in a way that does not require manual entries. Manual entries are slow and prone to errors.

- **Check for data consistency:** It is important to check the data in the catalog for consistency and to identify possible typing mistakes (especially in the case of manual entries). In particular, it is recommended to check that all units used in the catalog are consistent, as several test results can be reported with different units.

- **Coordination with data providers:** As mentioned above, the data provided to the research team was supplied by fuel farm operators, testing laboratories, or fuel companies. It is important to keep in close contact with them to ensure that the data continues to be provided. In the relatively short span of this project, there were certain changes that led to a discontinuation in the data collection. For example, there was a change from one testing company to another at a fuel farm and the new testing company was not aware of the data feed for this project. For the purposes of establishing a more comprehensive catalog, this is an important area to keep in mind to ensure data continuity.

6.4 Potential uses for the catalog

There are many potential uses for the fuel properties catalog. A main goal for creating the catalog is to monitor the variability in jet fuel properties over time, especially as alternative jet fuels get introduced into the jet fuel pool. Nobil Petroleum has been maintaining a catalog of jet fuel properties for over ten years and has experience analyzing and visualizing trends in jet fuel data. For example, using data collected from eight-point test results of conventional jet fuel samples from airports in the New York metropolitan area, Nobil Petroleum produced two charts showing the variability in freezing point and density over a twelve month period (see Figure 15 and Figure 16, respectively). Although individual test results appear to vary, all these samples were within specification and demonstrate the natural variability in conventional jet fuel properties.

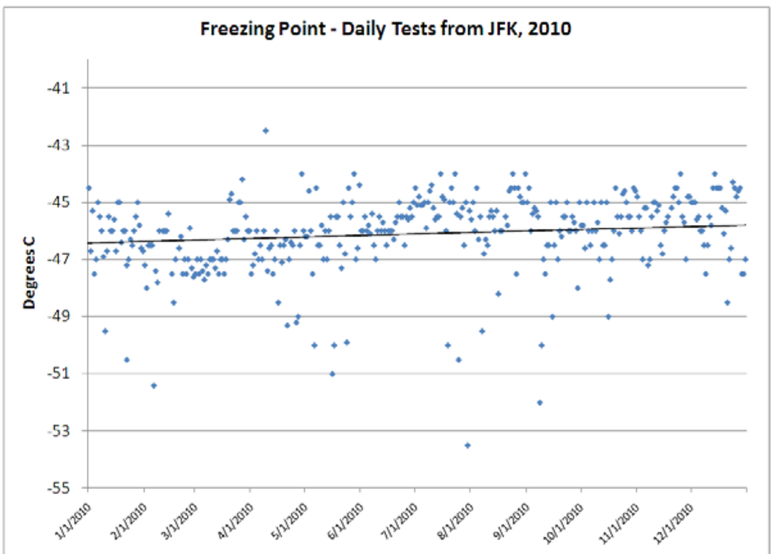

Figure 15: Variability in freezing point for a set of fuel samples collected in 2010.

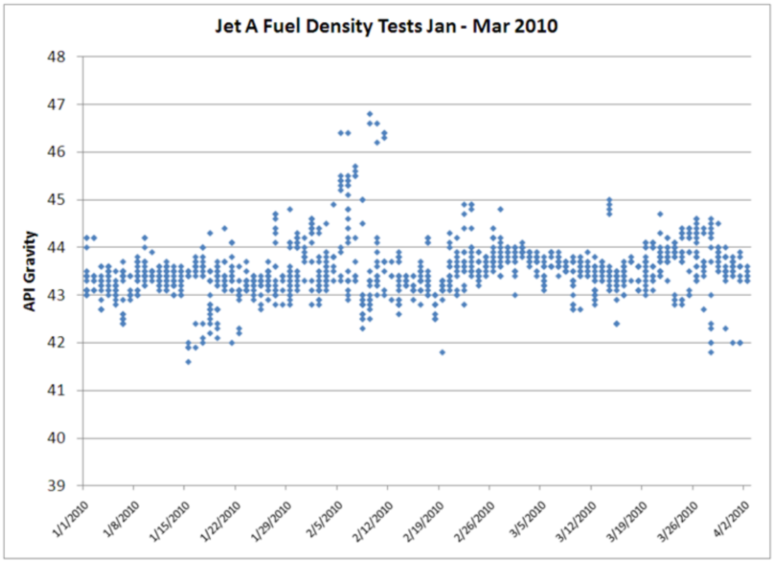

Figure 16: Variability in density for a set of fuel samples collected in 2010.

Another potential use for the catalog would be to serve as a repository of fuel properties data for different types of users. For example, airlines and airport operators may be interested in gaining a better understanding of fuel properties across the U.S. For example, airlines that want to purchase alternative jet fuel would benefit from understanding where conventional jet fuel with high density is more likely to be available to use as blendstock. Other properties, such as freeze point, can also be important for airline dispatchers as they plan flight routes, in particular polar routes. Airlines for America operates a jet fuel information dashboard (the Fuel Portal) and it could serve as a convenient outlet for the information contained in the catalog.

The catalog could also be available to non-airline and non-airport users. For example, alternative fuel producers would be interested in understanding the variability of jet fuel properties across the country. Furthermore, making the fuel properties catalog available to academia and the general public may spur further research and innovation related to jet fuel distribution and handling. Two possible outlets for a "public" version of the catalog are the Commercial Aviation Alternative Fuels Initiative (CAAFI, www.caafi.org) and the Department of Energy's Alternative Fuels and Advanced Vehicles Data Center (http://www.afdc.energy.gov/afdc/applications.html).

Observations from implementation of the catalog

The airline that facilitated obtaining the data on conventional jet fuel to populate the catalog has been very interested in the ability to analyze the data for the identification of potential trends. More data needs to be collected in order to have large enough sample sizes to perform analysis with statistical significance. Furthermore, in order to identify seasonal variations, it will be necessary to collect data spanning a number of years.

6.5 Access to data

We did not anticipate any problems in the collection of limited amounts of data to populate the prototype catalog. Our approach was to collaborate with a major U.S. airline to get access to the information.

Observations from implementation of the catalog

In our experience, the key to obtaining the data was for an airline to request a fuel supplier, fuel farm operator, or testing laboratory to make it available to us. As long as the airline communicated with those entities, there were no difficulties in collecting the data.

7 Glossary

Term	Definition
AFM	Aircraft Flight Manual
AFQRJOS	*Aviation Fuel Quality Requirements for Jointly Operated Systems*. JIG checklist for fuel handling at airports.
Alcohol to jet (ATJ)	Synthetic jet fuel made from alcohols.
API	American Petroleum Institute
API 1543	*Documentation, Monitoring and Laboratory Testing of Aviation Fuel During Shipment from Refinery to Airport*: recommended practices for shipment of fuel.
API 1595	*Design, Construction, Operation, Maintenance, and Inspection of Aviation Pre-Airfield Storage Terminals*: recommended practices for handling of fuel and operation of storage facilities.
ASTM	ASTM International, a voluntary standards development organization, develops specifications used for the certification of jet fuels with input from government agencies, fuel manufacturers, aircraft and engine manufacturers, and airlines.
ASTM D1655	ASTM jet fuel specification
ASTM D7566	ASTM approved a new fuel specification, "Aviation Turbine Fuel Containing Synthesized Hydrocarbons.”
A4A	Airlines for America
ATA 103	*Standard for Jet Fuel Quality Control at Airports*: This sets the standards for every aspect of getting fuel from the delivery point on the airport up to the wing of the aircraft.
Biofuel	Fuel produced from biomass, which is organic matter available on a renewable or recurring basis, including agricultural crops, wood and wood residues, plants (including aquatic plants), grasses, animal residues, and municipal waste.
CAAFI	See "Commercial Aviation Alternative Fuels Initiative."
Certificate of Analysis (COA)	Paperwork issued for each batch of fuel by an independent fuel testing laboratory to certify the fuel meets specification.
CO_2	Carbon dioxide
Commercial Aviation Alternative Fuels Initiative (CAAFI)	A coalition of airlines, aircraft and engine manufacturers, energy producers, researchers, international participants and U.S. government agencies working to further the deployment of alternative jet fuels for commercial aviation.
DEFSTAN 91-91	*Turbine Fuel, Aviation Kerosene Type, Jet A*, which is the specification used for most civil aviation fuels outside the United States. It is published by the UK Ministry of Defence.
Drop-in fuel	Nonpetroleum fuel that is compatible with existing infrastructure and uses for petroleum-based fuels.
EI	The Energy Institute (UK)

Term	Definition
FAA	United States Federal Aviation Administration
Fermentation Renewable Jet	Biofuel created by a synthetic biology process in which metabolic processes involved in fermentation have been co-opted by genetically modifying organisms to produce hydrocarbons in place of ethanol.
Fischer Tropsch Process	A catalyzed chemical reaction in which synthesis gas, a mixture of carbon monoxide and hydrogen, is converted into liquid hydrocarbons of various forms.
FT	Fischer-Tropsch.
GHG	Greenhouse gas
Greenhouse gases	Gases that trap heat in the atmosphere. Principal greenhouse gases caused by human activities are carbon dioxide, methane, nitrous oxide and fluorinated gases.
HRJ	Hydrotreated Renewable Jet.
HEFA (also Hydrotreated renewable jet)	Synthetic fuel made from hydroprocessed esters and fatty acids (biological sources).
ATJ	Alcohols-to-Jet -process that uses alcohols as feedstock to produce alternative jet fuel and other by-products.
IATA	International Air Transport Association.
ICAO	International Civil Aviation Organization.
JIG	Joint Inspection Group
JIG 1	Guidelines for Aviation Fuel Quality Control & Operating Procedures for Joint Into-Plane Fueling Services.
JIG 2	Guidelines for Aviation Fuel Quality Control and Operating Procedures for Joint Airport Depots.
JIG 3	Guidelines for Aviation Fuel Quality Control and Operating Procedures for Jointly Operated Supply and Distribution Facilities
OEM	Original equipment manufacturer; in this document refers to aircraft and or engine manufacturing companies.
Refinery Quality Certificate (RQC)	Original Document describing the quality of the fuel, and determination of all properties required in the relevant specification,
Release Certificate	Is attached to every fuel transfer; signed by an authorized person and certifies conformity with applicable specifications as per API-1543 recommended practices
SPK	Synthetic paraffinic kerosene.
SAE	Society of Automotive Engineers

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FR-28855
21 December 2020

CONTINUOUS LOWER ENERGY, EMISSION, AND NOISE (CLEEN II)

HIGH-PERFORMANCE CORE, ULTRA-HIGH BYPASS RATIO, GEARED DUCTED PROPULSION SYSTEM

FINAL REPORT — PUBLIC RELEASE

PERIOD OF PERFORMANCE: 10 OCTOBER 2015 TO 31 DECEMBER 2020

Prepared for

Federal Aviation Administration
800 Independence Ave SW
Room 406
Washington, DC 20591
Attention: Levent Ileri

Prepared by

Pratt & Whitney, a division of Raytheon Technologies Corporation
400 Main Street
East Hartford, CT 06118 USA

In Response to
Contract No. DTFAWA-15-A-80010

TECHNICAL CONTACT: Stephen Gatto
TELEPHONE: (860) 565-8266
EMAIL: stephen.gatto@prattwhitney.com

CONTRACTS CONTACT: Kim Sansone
TELEPHONE: (860) 565-2690
EMAIL: kimberly.sanone@prattwhitney.com

PRATT & WHITNEY DEPENDABLE ENGINES

GO BEYOND

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EXECUTIVE SUMMARY

Pratt & Whitney (P&W) successfully concluded all activities included as part of the technology maturation efforts covered by the Federal Aviation Administration's (FAA) Continuous Lower Energy, Emissions, and Noise (CLEEN) II Program as outlined in DTFAWA-15-A-80010. This proposal addresses the FAA's objective to develop continuous lower energy, emissions, and noise technologies for civil subsonic airplanes under the CLEEN II program, which is a follow-on to CLEEN I program.

P&W's intent with this program was to further develop, design, and validate advanced core-engine technologies that were aimed at improving the thermal efficiency of the current generation of the PurePower® Geared Turbofan™ (GTF) engine, as well as the next generation (NextGen) of GTF engines. The core improvements, when integrated with the ultra-high bypass (UHB) ratio GTF Propulsor previously developed under the FAA CLEEN I program, is estimated to deliver a total of 25% fuel burn reduction, relative to a year 2000 best in-class aircraft, such as the Boeing 737-800. This represents a significant contribution to the achievement of FAA CLEEN Program fuel burn reduction goals.

The contracted work included development of compressor and turbine technologies that will enable higher overall pressure ratio (OPR), higher compressor exit temperature (T3), and higher turbine inlet temperature (T4) for future GTF engines. These characteristics enable the advanced cycle and unique architecture that, when combined with the innovative, UHB ratio GTF Propulsor and result in a gas turbine engine that has the best-in-class thermal and propulsive efficiencies.

Specifically, P&W was successful with the development and demonstration of advanced turbine engine core technologies — even in the face of a global pandemic — achieving all program goals for technology advancement on-time and on-budget in the following areas:

- Compressor aero-efficiency technology for a higher polytrophic efficiency to TRL-6 under the CLEEN II contract and to TRL-7 under a continued P&W initiative
- High-OPR, high-T3 compressor technology for higher temperatures and core thermal efficiency
- Turbine aero-efficiency technology for a higher turbine adiabatic efficiency to TRL-6
- Application of advanced materials technologies and an innovative design that supports non-film cooled turbine design technology to TRL-5, enabling the removal of a significant amount of cooling (about 50%) and corresponding losses to achieve a higher thermal efficiency and corresponding fuel burn benefit.

The high compressor aero-efficiency development objectives to characterize inlet flow, determine sensitivities relative to distortion, bleed, Reynolds number, vane design and their impacts to transient operability of the compressor were validated in both a 2016 full-scale rig and both a ground and flight engine demonstrator. These compressor efficiency improvements were concluded in 2019 with an on-time flight test in an existing GTF product line asset demonstrating 2.2% performance improvement, 0.5% efficiency improvement, and a high power stability improvement of as much as 7%.

Under the CLEEN II contract, P&W initiated conceptual design of the advanced adiabatic turbine system. The program validated a new turbine blade concept technology, initiated in 2015, with two single element cascade rigs before finalizing single element casting designs that were procured in expectation of a full-scale single stage turbine test that completed in late 2020. This full-scale testing was completed at the new state of the art turbine test facility designed, built and commissioned under this FAA CLEEN II contract at the Pennsylvania State University (PSU). The Steady Thermal Aero Research Turbine (START) facility is a high-speed aero durability single stage test asset with unique and innovative measurement capability that yields high fidelity, pressure and thermal measurements.

In all, the FAA CLEEN II scope executed by P&W, with the support of the FAA, offered a strategy that helped develop advanced, aerodynamic-efficiency-related technologies that have been applied to current and planned

future products for improved fuel burn. Some of the aforementioned technologies have already made environmental impacts on the current fleet of NGPF aircraft. The successful CLEEN II technologies developed under this contract can enable product improvement capability and environmental benefits for future propulsion impacting impacting 2025+ Entry Into Service (EIS) commercial programs with 1.4% fuel burn benefit expecting a reduction of more than 29,000 gallons of fuel per plane annually.

CLEEN II success, even under 2020 unprecedented circumstances, demonstrates P&W's commitment to continued technology advancements, environmental responsibility, and customer expectations. Achievement in these areas are supporeted by P&W's long term committed technology programs, such as FAA CLEEN, tremendous personnel with experience and expertise using the most advanced computational tools, processes, and validation facilities.

P&W's succesful completion of the CLEEN II program is another key step in P&W's and the overall aviation industry's advancement toward cleaner, more environmental responsibility flight, we look forward to future opporopportunities with the FAA to make a meaningful impact on a sustainable aviation market that benefits civil transportation while reducing the ecological footprint.

CONTENTS

Section ***Page***

FIGURES

Figure ***Page***

Figure ***Page***

TABLES

ACRONYMS

A

AWS	Aft Wheel Space

B

BOAS	Blade Outer Air Seal

C

CFD	Computational Fluid Dynamics
CLEEN	Continuous Lower Energy, Emissions, and Noise

D

DDP	Durability Design Point
DOE	Design of Experiments

E

EDM	Electric Discharge Machining
EIS	Entry Into Service
EWC	Endwall Contouring

F

FAA	Federal Aviation Administration
FBR	Fuel-Burn Reduction

G

GIS	Geographic Information Systems
GTF	Geared Turbofan

H

HPC	High Pressure Compressor
HPT	High Pressure Turbine

I

IMC	Intermediate Case
IR	Infrared

K

KE	Knife-Edge
KMPS	Kulite Miniature Pressure Scanner

L

LPC	Low-Pressure Compressor

M

MRL	Manufacturing Readiness Level

N

NextGen	Next Generation
NGPF	Next Generation Product Family
NOx	Nitrogen Oxide
nvPM	Nonvolatile Particulate Matter

O

OPR	Overall Pressure Ratio

P

P/S	Pressure Side
P&W	Pratt & Whitney
PLC	Programmable Logic Control
PoE	Power Over Ethernet
PR	Pressure Ratio
PRT	Platinum Resistance Thermometer
PSU	Pennsylvania State University
Pt	Total Pressure
PTFE	Polytetrafluorotheylene

R

RPCL	Rapid Prototype Casting Lab
RTRC	Raytheon Technologies Research Center

S

SEC	Single-Element Cascades
SP	Speed Parameter
START	Steady Thermal Aero Research Turbine
SVS	Stator Vane Schedule

T

TDC	Top-Dead-Center
TOBI	Tangential On-Board Injection
TRL	Technology Readiness Level
Tt	Total Temperature

U

UHB	Ultra-High Bypass
UT	Ultrasonic

1. INTRODUCTION

1.1 OVERVIEW OF CORE TECHNOLOGIES

Under the FAA's CLEEN II effort, P&W conducted rig testing of new engine core technologies within the High-Pressure Compressor (HPC) and the High-Pressure Turbine (HPT).

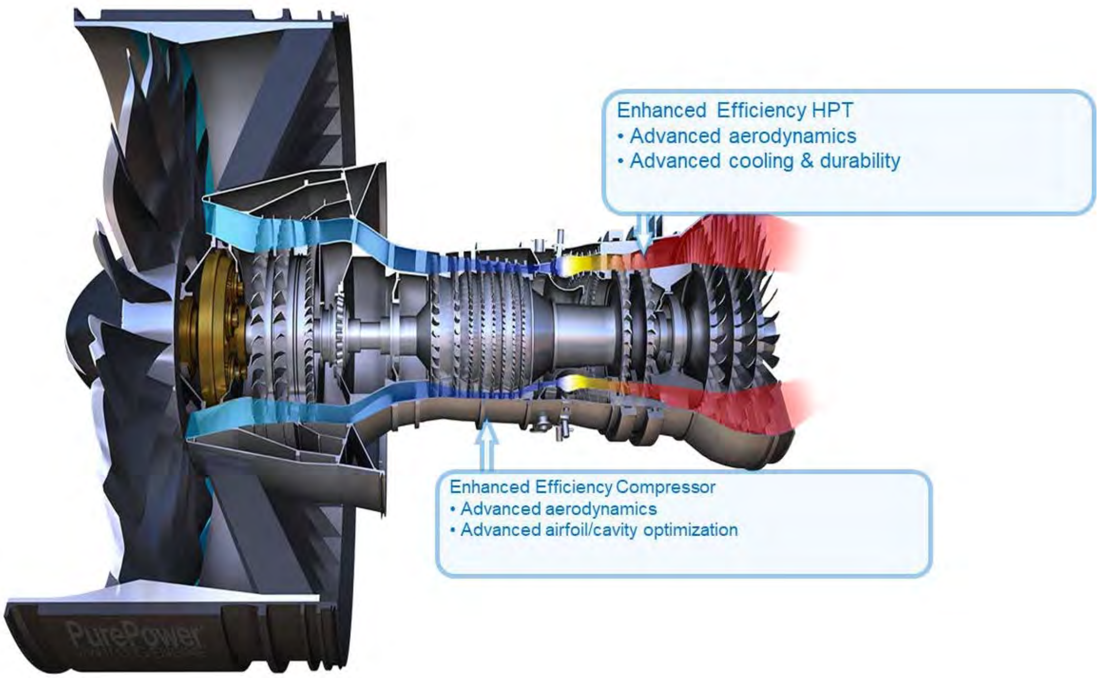

Figure 1-1. *Pratt & Whitney's Geared Turbo Fan Engine with CLEEN II Core Technologies*

The technology suite for the HPC consisted of optimizing the shape for the HPC blades and vanes as well as the cavities located between stages in order to minimize aerodynamic losses. The estimated target fuel burn benefit at the start of the program was a 0.8-1.0% reduction at the system level.

Prior to the FAA CLEEN II contract, P&W had been developing the conceptual and detailed design for a new HPC architecture and configuration. With the help for the FAA, P&W was able to validate the technologies in a module rig test.

The technology suite for the HPT consisted of integrating new concepts in cooling circuitry, cooling hole shape optimization, and new aerodynamic shapes. The estimated target fuel burn benefit at the start of the program for the HPT technologies was also 0.8 to 1.0% reduction at the system level.

With the help of the FAA, P&W designed, built, and tested scaled airfoils with novel cooling hole shapes to tailor film cooling effectiveness for the internal environment of the turbine. Using new methods of instrumentation, P&W was able to quantify film cooling effectiveness. This allows for future designs to reduce the amount of film cooling air necessary in order to effectively protect turbine blades from degradation. Thus reducing overall fuel consumption at the system level.

Also performed under this effort was the design, manufacture and testing of full-scale hardware embodying advances in internal cooling circuitry design and external aerodynamic shapes. The CLEEN II Technology Blade progressed advancements in manufacturing using a new method of creating internal cores for single crystal casting manufacturing. Using the new methods, P&W was able to integrate extremely detailed core features. This directly paves the way for integrating novel manufacturing methods into our production for future product offerings.

Integrated into the Technology Blade design was a 3-dimensional optimized airfoil that took advantage of new core designs to effect cooling efficiency over the surface of the airfoil.

These HPT technologies, combined with the HPC module technologies, enables P&W to offer future products that reduce effort required to compress flow as well as required cooling flow so that the engine can run more efficiently with less fuel consumed.

1.2 COLLATERAL BENEFITS

The compressor and turbine technologies funded with help by the FAA CLEEN II program have improved the way P&W designs commercial products. Module level validation has and will continue to prove out technologies to Technology Readiness Level (TRL)-6 and enables higher efficiency compressors and turbines for a successful entry into service for the next commercial product offering by P&W. Those same analytical tools and design practices used for the design and validation of the CLEEN-funded compressor and turbine demonstrations are also being used to expand the envelope on military engines.

Also with the assistance of the FAA under the CLEEN II program, P&W has been able to make advancements in manufacturing readiness Level (MRL) for advanced turbine hardware casting and machining. Inclusion of new methodologies and technologies necessary to create the advanced HPT blade used in the START rig were made possible by the CLEEN II program. The application of these benefits is not limited to the GTF engine, but across all of P&W's future product lines.

1.3 PROGRAM EXECUTION

The FAA CLEEN II program spanned from October 2015 to December 2020. The original plan was for the program to close in September of 2020; however, a three-month facility shutdown at PSU in mid-2020 due to the COVID-19 pandemic forced the program to be extended by the same duration. Even with this delay, the program completed on-budget and compliant to the 50/50 cost share split with all technical milestones successfully met. The timeline in ***Figure 1-2*** shows the revised schedule due to the COVID-19 impacts.

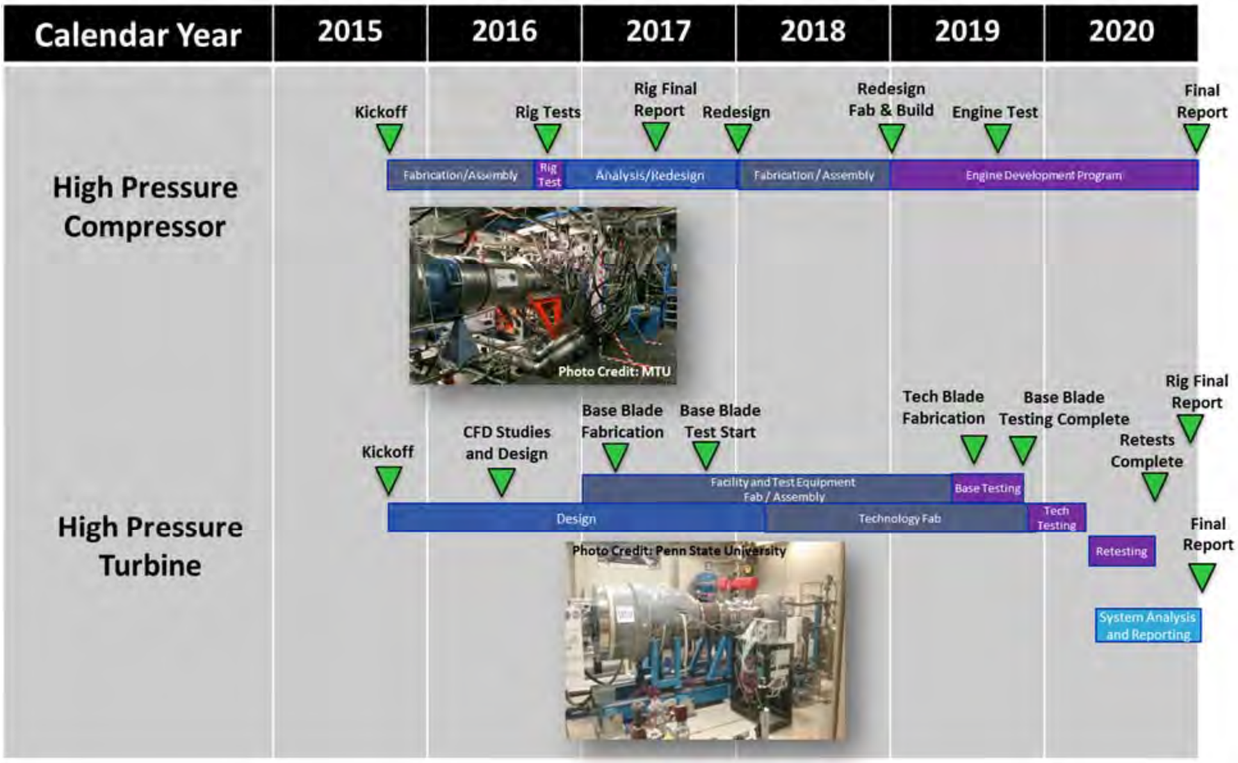

Figure 1-2. *CLEEN II Program Schedule*

2. HIGH-PRESSURE TURBINE CORE TECHNOLOGIES TESTING

2.1 INTRODUCTION

The cooling of the airfoils within a modern HPT presents a formidable challenge due to the high operating temperatures needed to support optimized cycles for reduced fuel burn. So, as engines become more fuel efficient, turbine inlet temperatures continue to increase beyond the temperature capability of turbine airfoil materials. It is therefore necessary to have effective cooling designs in order to protect turbine components from the hot mainstream gases. The air used for cooling purposes is extracted from the high-pressure-compressor stages, which results in a performance penalty because the cooling air bypasses some of the work extraction of the first turbine stage. Therefore, for optimum performance, it is necessary to minimize the amount of turbine cooling.

The portion of the CLEEN II program detailed here focuses on the design and testing of new HPT air-foil-cooling and design philosophies in order to demonstrate their improved efficacy and advance their TRL in preparation for product applications. In order to minimize the cooling air required to meet life and efficiency metrics, both passive- and active-cooling methods were utilized during the design of the CLEEN II HPT. Passive methods comprise modifications of the airfoil profile/geometry to reduce the external connective heat-load distribution, while active methods typically entail internal convective and external film-cooling mechanisms.

The design of film-cooling configurations for HPT airfoils is inherently a multi-disciplinary endeavor. Two of the main disciplines involved are turbine durability and aerodynamic performance. Turbine durability relies on film-cooling to effectively protect the metal surface from the hot mainstream gases and reduce the overall part temperature and subsequently maximize the life of the turbine. Moreover, it is desirable that any mixing losses or additional profile losses caused by film-cooling are minimized in order to achieve optimal aerodynamic performance. There exists a vast parameter space associated with film-cooling performance (including blowing rates, hole geometry, and airfoil loading, to name a few) which has led to various experimental studies which focus on either heat transfer and/or aerodynamic performance optimization for film cooling.

The investigation of the durability and aerodynamic aspects of the new technologies tested under CLEEN II took place in two main phases: small-scale, Single-element Cascade (SEC) testing, and full-scale rotating rig testing. Theoretical and design work had already been largely completed prior to the CLEEN II contract, and so will not be detailed in this section. The main facilities used were the Raytheon Technologies Research Center (RTRC) and the START Rig at PSU, both of which provide state-of-the-art testing capabilities.

2.2 TEST PLANNING AND EXECUTION

Completion of the planned test program required manufacture of a set of technology blades (hereafter referred to as the tech blades) as well as the design, manufacturing, and integration of upgrades to the START Rig to allow for the necessary data gathering. Two important upgrades were the addition of an Infrared (IR) camera system to allow for thermal imaging of airfoil surfaces for durability analysis as well as a 360-degree traversing set of pressure and temperature rakes (hereafter called the 360 degree Traverse) to allow for high fidelity performance measurements. The challenges associated with these prerequisite sets of equipment largely drove the scheduling efforts for the entire program.

The baseline set of turbine blades (rotating airfoils) comprised a set of production blades and so did not require special design, manufacturing, or procurement efforts. The tech blades however, incorporated new cooling and aerodynamic features. PSU and P&W worked to streamline the testing process in order to minimize the effect of hardware availability on the whole program schedule. This was largely successful as significant amounts of time were cut from the originally planned testing period.

Finally, after all components were manufactured and testing was completed, challenges relating to malfunctioning instrumentation discovered during the last planned set of tests, along with the COVID-19 pandemic and ensuing facility shutdown, resulted in the need to add an additional set of tests later in 2020. This represented an approximate 3-month extension of the period of performance (equivalent to the length of COVID facility shutdowns) and two new sets of aero-efficiency tests in August and September of 2020. ***Figure 2-1*** and ***Table 2-1*** represent the final executed CLEEN II program schedule and milestones.

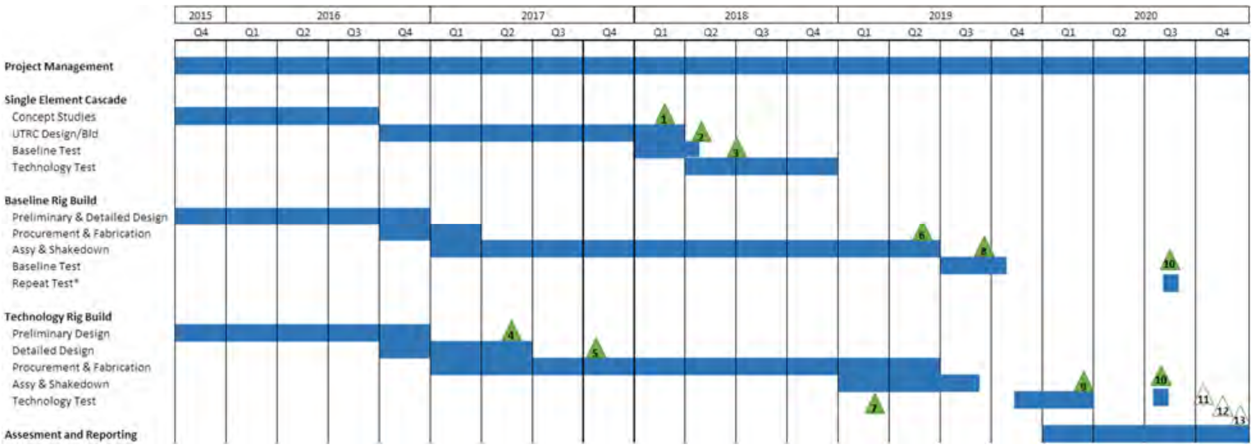

Figure 2-1. *Final Overall CLEEN II HPT Schedule With Milestones*

Table 2-1. *Final Overall CLEEN II HPT Milestone Dates*

Milestones	***Planned Date***	***Complete Date***
1. Cascade Build Complete	2/9/2018	2/9/2018
2. Cascade Test 1	4/13/2018	4/13/2018
3. Cascade Test 2	6/30/2018	6/28/2018
4. Rig PDR	5/19/2017	5/19/2017
5. Rig DDR	10/26/2017	10/26/2017
6. Rig Baseline Testing Start	9/1/2017	8/30/2017
7. Rig TRR	2/26/2019	2/26/2019
8. Baseline testing complete	12/17/2019	12/17/2019
9. Tech blade testing complete	3/12/2020	3/11/2020
10. Repeat efficiency testing complete	9/25/2020	9/22/2020
11. Informal Test Review	11/16/2020	11/16/2020
12. Test Report	11/30/2020	11/30/2020
13. System Level Assessment	12/15/2020	12/15/2020

2.3 FACILITY AND RIG

2.3.1 Overview

As previously mentioned, the CLEEN II HPT testing was conducted at the START laboratory located at the Pennsylvania State University within the University Park campus in State College, Pennsylvania. The Penn State turbine facility supports testing of true-scale, rotating engine hardware with continuous and steady air flow at elevated pressures and temperatures to provide aerodynamic- and thermal-condition similitude to the engine. This world-class research facility was established in 2011 as a collaboration between U.S. academia, industry, and government to further advance the development of modern gas turbine engines and support the aircraft propulsion and land-based power generation industries. Funding was provided to construct the facility and rig from three primary research sponsors including Penn State University, Pratt & Whitney, and the Department of Energy - National Energy Technology Laboratory.

The pursuit of ever-increasing engine efficiency has driven core temperatures higher and higher. Core temperatures in modern engines are often well above the thermal capabilities of the materials involved. Safely operating such an engine requires the use of active cooling to protect these materials and ensure longevity and durability of the relevant engine components. Therefore, the engines are designed to transfer a certain amount of relatively cool, high-pressure air directly to the turbine section through a series of secondary paths and cavities that are located radially inward and outward from the main gas path annular walls. This cooler airflow (termed secondary air) originates from the upstream compressor section, where a portion of the compressor main air flow is strategically bypassed around the combustion chamber. Within the turbine, the cooling air is used to thermally protect the metal hardware including the stationary vanes, platforms, rotating blades, and disks. The cooling air is also employed to reduce or eliminate ingestion of the hot main-gas-path flow into the cavity spaces between adjacent stationary and rotating hardware. This requirement for secondary air extraction for cooling reduces the overall cycle efficiency of the engine through the loss of air from the main gas path as well as creating avenues for leakages in the routing of airflow amongst rotating and stationary hardware. So, with these complex, multi-disciplinary considerations in mind, the PSU START rig facility was designed to support the study of product-relevant improvements.

The START research facility was specifically designed to focus on these important turbine aerodynamic and heat-transfer challenges by providing a heated, engine-relevant environment with the necessary cooling and data-gathering capabilities to study a large variety of different test objectives. Design studies were first conducted to establish the requirements for the necessary engine-relevant conditions to support the capture the most useful data possible. These design studies also helped determine the rig-infrastructure power requirements, which were substantial and required extensive equipment and power grid modifications to support. These substantial power requirements necessitated integration of advanced safety and control systems to maintain the turbine shaft speed and allow the turbine blades to operate at engine-relevant ratios of axial to circumferential air-flow velocities. All of these facility-design measures helped to ensure fundamental aero- thermal parameters, such as Reynolds numbers and Mach numbers, were matched to the engine-relevant conditions.

Prior to construction, a facility like the START lab did not exist at a university in the United States, representing a major deficiency in the ability for U.S. industry and academic institutions to study and understand these topics. The ultimate result of such a deficiency is a competitive disadvantage in the design and manufacturing of the most efficient and highest-performing turbine engines possible. With its establishment and commissioning, the START laboratory at Penn State represents a major achievement for the U.S. to support its competitive edge in turbine engine development. It also represents a fantastic incubator of knowledge for continuing generations of engineers and scientists to study these topics, as evidenced by the great number of Ph.D. and graduate students assisting with the CLEEN II work, as well as the large number of research activities slated for future study in the START rig.

2.3.2 Facility Construction

Facility construction began with site selection in 2011. A site was selected within an existing Penn State research facility, an approximately five-minute drive from the main campus (***Figure 2-2***). Plans were then created to renovate the space for the required research and support equipment. Both indoor and outdoor equipment would be needed.

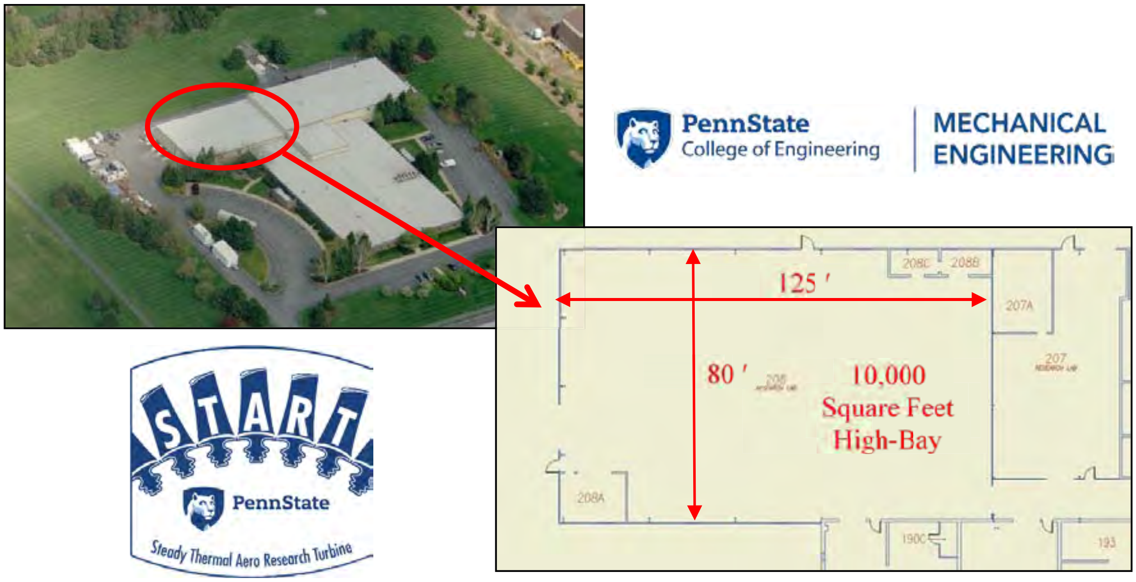

Figure 2-2. *Aerial View of the START Facility Prior to Construction*
A high-bay area in the back of this building was selected for renovation into the START facility. Location: State College, PA

Three primary rooms were planned in order to isolate the turbine test area from both the air flow source equipment and the human command center. The facility design plan consisted of an air compressor room, turbine test room, and a control room, as shown in ***Figure 2-3***. The rooms were sized appropriately to incorporate the necessary equipment and support equipment and infrastructure, as well as human access and support. The command center was designed with safety as a main focus, incorporating the use of ballistic windows.

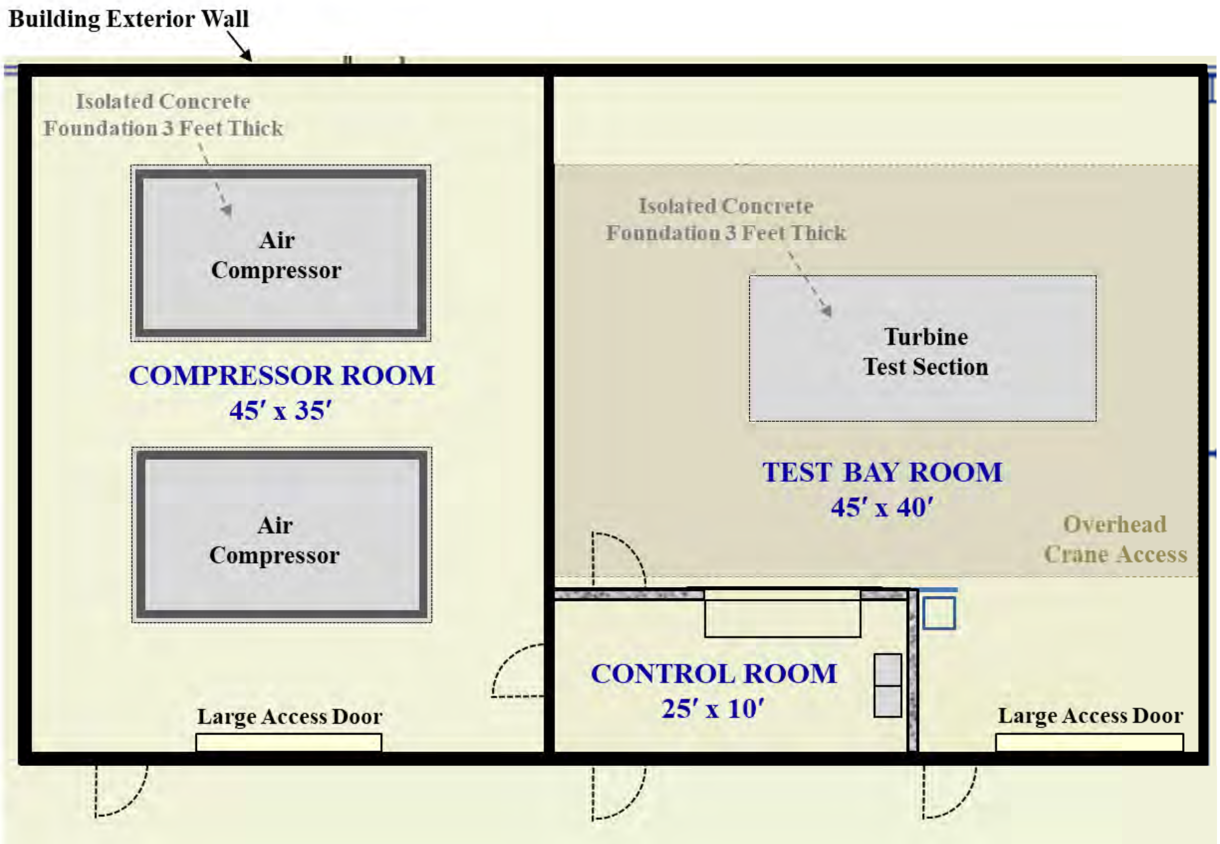

Figure 2-3. *Layout of START Facility Rooms*

The walls of the new facility were specially designed to help contain the sound levels from the rig from spreading throughout the building. Additionally, three isolated concrete foundations were poured to separate the rooms from each other and from the main building. These foundations were a special design feature, which included steel-reinforced concrete slabs approximately three feet thick. The intent was to create very large and strong slab masses that are decoupled from the building concrete floor to eliminate vibration transmission to and from the high-speed rotating hardware within the air compressors and the test turbines. Vibration-isolation joints were also incorporated within all four perimeter seams of each foundation. The renovation of the rooms and space were completed in mid-2012 (***Figure 2-4***) and included the addition of an overhead crane for use in equipment installation as well as rig-configuration teardowns and changeovers. The completed state of the test-facility space is shown in ***Figure 2-5***.

Figure 2-4. *Renovation and Construction Work Performed at the START Facility Building in 2012 Within the Large High-bay Room. Image credit: PSU*

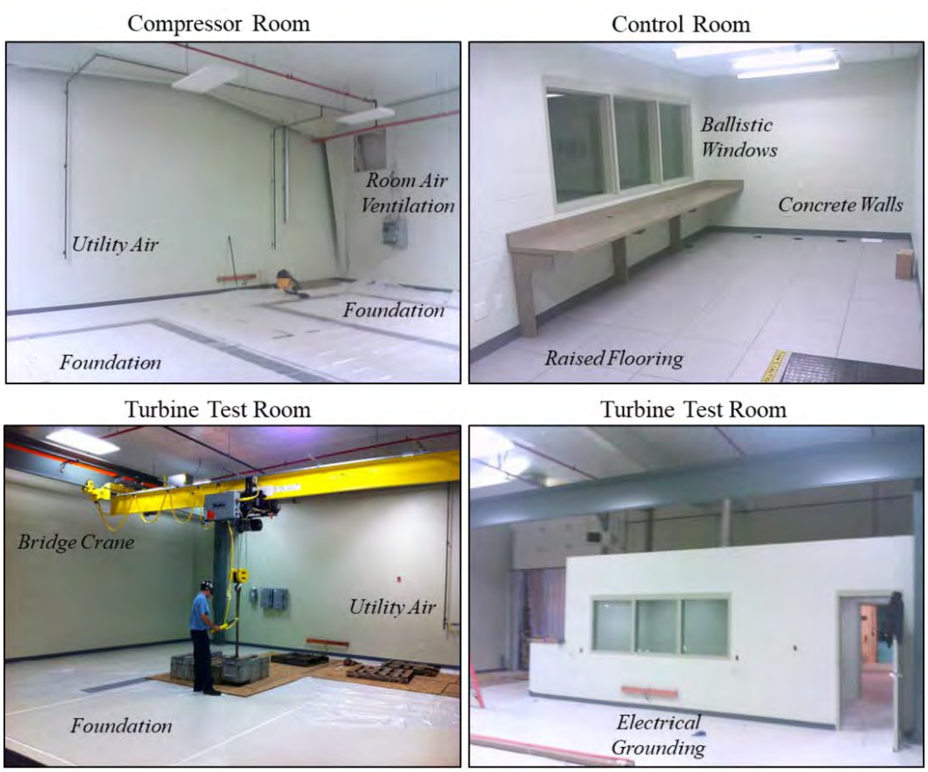

Figure 2-5. *Renovation Completed at the START Facility In mid-2012 Including the Compressor Room, Control Room, and Turbine Test Room. Image credit: PSU*

Upon completion of the test facility space, the sourcing and procurement of test equipment and infrastructure began in the second half of 2012. It was initially planned to first fully integrate one compressor, along with its testing and commissioning, before continuing with the second compressor and additional components. This first compressor, a centrifugal style two-stage machine, was delivered in 2012, with the final completion of piping, fittings, and other necessary equipment being finished in 2014. A single compressor can discharge air at a rate up to approximately 11,000 SCFM. The electrical power requirement to operate a single compressor was approximately 1.1 MW. After incorporation of this first air compressor, it was planned to demonstrate its capabilities by supplying compressed air flow to a test turbine with partial-span vanes and blades (relatively short in height).

With the single air compressor integrated into the facility and successfully demonstrating its use to supply air flow to the preliminary, partial-span test turbine, a second air compressor was acquired. The second air compressor was delivered to the START facility in 2014 and its integration was completed in 2016, including its piping system and electrical equipment. The addition of the second air compressor raised the air flow rate capacity of the facility to approximately 22,000 SCFM. The electrical power requirement to simultaneously operate both compressors was therefore also raised to nearly 2.2 MW. ***Figure 2-6*** shows the stages of compressor procurement and integration.

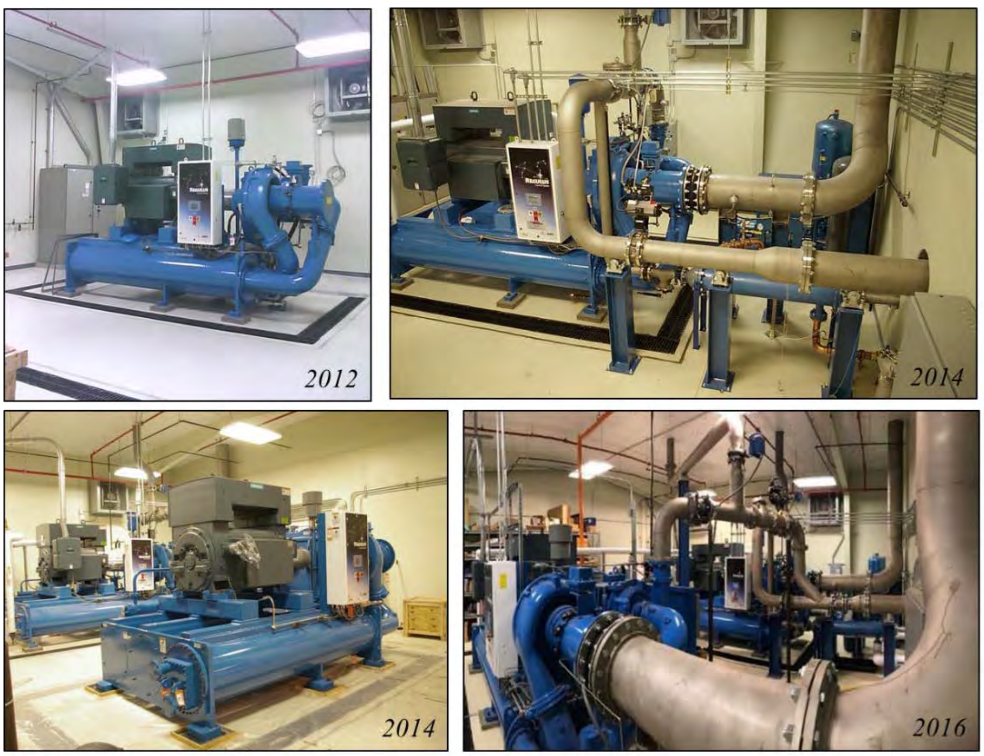

Figure 2-6. *Compressor Room at Different Stages of the START Facility Evolution. Image credit: PSU*

Showing the first air compressor system delivered in 2012 (upper left) and its air piping connections completed in 2014 (upper right); the second air compressor system delivered in 2014 (lower left), and both air compressor systems fully integrated with piping into the rig in 2016 (lower right).

As capabilities of the START facility continued to expand, so too did the infrastructure demands necessary to support the system. Among the required upgrades were electrical additions of a new dedicated 46 kV electrical power line and substation (***Figure 2-7***), a significant increase to automated air-handling capacity in the compressor rooms, and a continuous supply of cooling fluid circulated to critical sub-system components (including an interstage air heat exchanger, an oil heat exchanger, and the necessary sub-components). This cooling system is sized to circulate approximate 250 gallons per minute of a water-glycol mixture to cool critical components while transferring the heat outdoors through a system of fans located 50 feet from the building (indoor pumps and equipment are shown in ***Figure 2-8***, while outdoor equipment is shown in ***Figure 2-9***). Also shown in ***Figure 2-9*** are an outdoor process chiller and underground water tank system. These systems are specifically dedicated to the test turbine operation and will be discussed in more detail in Section 2.3. The process chiller system was used specifically to thermally condition the turbine cooling air flowing through the secondary air system. The underground water tank and pump vault system were used specifically to circulate water to a dynamometer, mounted on the turbine test stand and coupled to the turbine shaft. The dynamometer and water system controlled and maintained the turbine operating speed.

Figure 2-7. *Dedicated Electrical Infrastructure Installed at START in 2013 Including a 46kV Electrical Line and Substation to Solely Support the Air Compressor Operation. Image credit: PSU*

Figure 2-8. *Indoor Circulation System for the Air Compressor Cooling Fluid Installed for the START Facility During 2013-2016. Image credit: PSU*

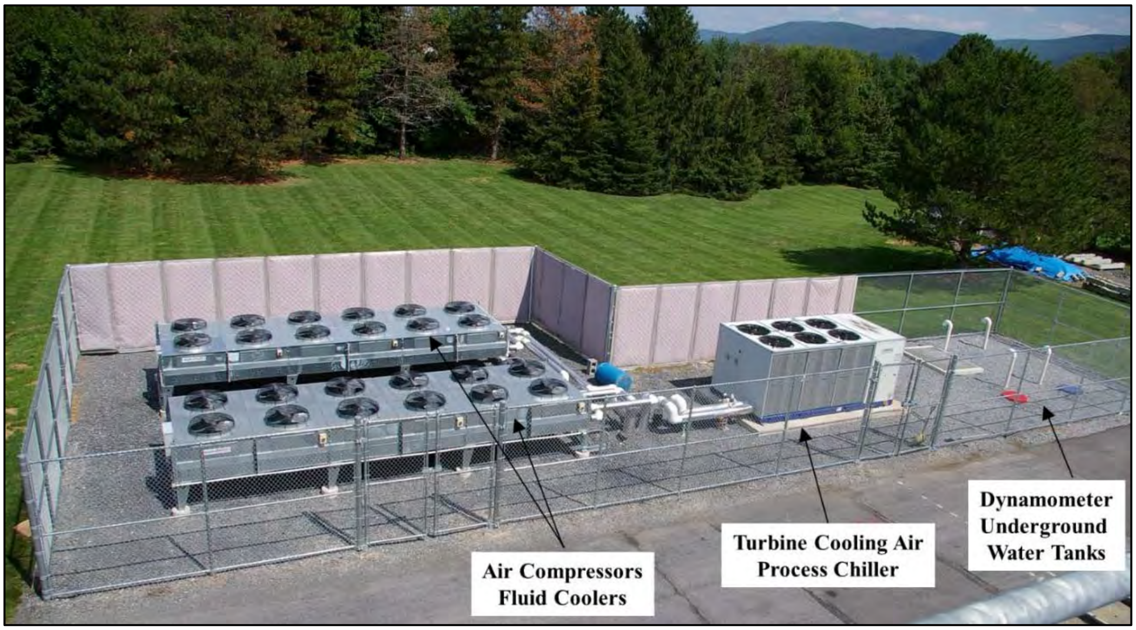

Figure 2-9. *Outdoor Large Cooling Systems for the Compressors and Test Turbines, Including an Underground Water Tank System, Installed for the START Facility During 2013-2016. Image credit: PSU*

To establish the elevated air temperatures passing through the main gas path and entering the test turbines, a natural gas delivery system was installed, as shown in ***Figure 2-10***. The natural gas system provided the necessary fuel required to operate a combustion-based heating chamber upstream of the turbine test section. The natural gas system and heater were both sized to adequately heat the combined total discharge flow from both air compressors up to a maximum temperature of 750°F (675°K). This heating system ensured that the main gas path air flow entering the test turbines would be at a high enough temperature to provide meaningful testing and heat transfer research. The two photographs located at the top of ***Figure 2-10*** show the natural gas delivery system, while the two lower photographs show the combustion-based heating chamber that conditions the air flow prior to the air flow entering the turbine test section.

Figure 2-10. *Natural Gas Delivery System Installed at START During 2016 and the Combustion-based Heater Chamber. Image credit: PSU*

The facility also incorporated a large steel platform that was installed above the compressor room on the building roof, as shown in ***Figure 2-11***. The platform was designed to support two inlet-filter weather hoods (one per air compressor), as well as a series of four industrial-grade exhaust silencers that reduced the sound levels of the exhausting flow. The inlet-filter weather hoods remove dirt and particulates from the air and were piped directly to the inlet of the air compressors. Two exhaust silencers were connected directly to the rig piping located downstream of the turbine test section, and the other two exhaust silencers were each piped directly to the unloading valves of the air compressors.

Figure 2-11. *Outdoor Roof Platform Installed Above the START Facility Compressor Room. Image credit: PSU*
Including the air flow intake systems and turbine exhaust silencers for a single air compressor operation in 2014 (left) and for dual air compressor operation in 2016 (right)

The facility control room was designed to incorporate the necessary operational equipment, as shown in ***Figure 2-12***, as well as advanced data acquisition and monitoring systems.

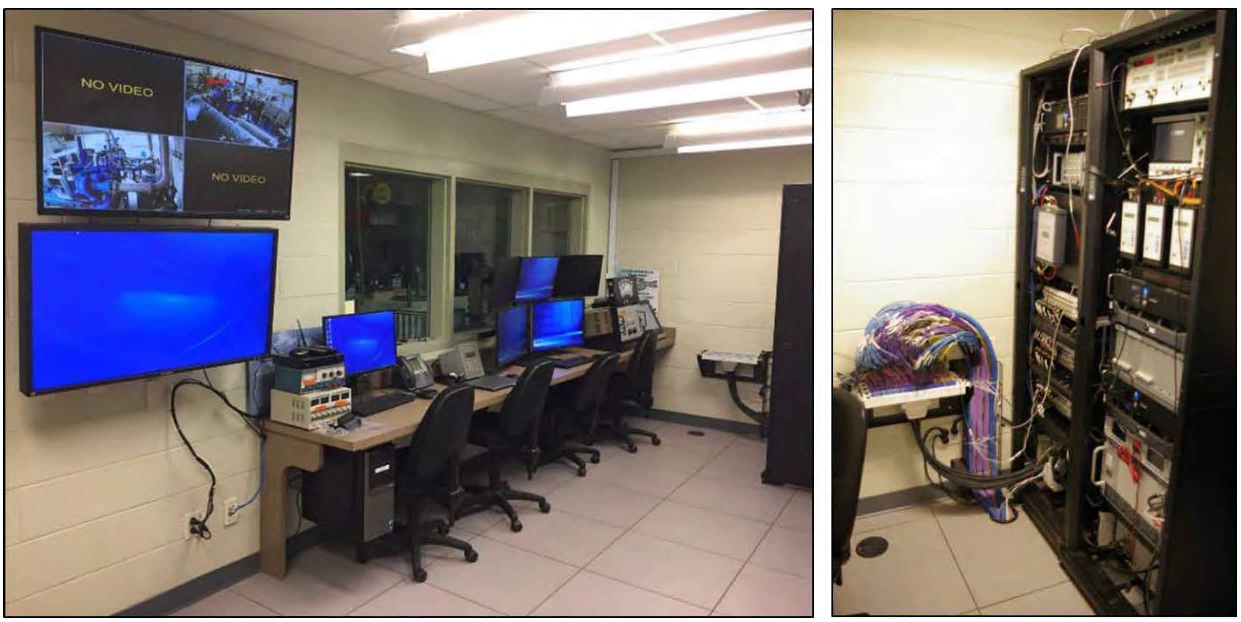

Figure 2-12. *START Facility Control Room Showing the Test Command Center and Data Systems. Image credit: PSU*

2.3.3 Test Rig Equipment

2.3.3.1 Rig Test Conditions

Throughout the process of designing and constructing the test rig and facility, primary focus was placed on sizing and selecting equipment to support test section conditions that offered the best engine representative environment and would produce the most meaningful learning of aerodynamic and heat transfer topics. The main gas path at the inlet of a high-pressure turbine is typically characterized by the air flow conditions that exit the combustor section of the engine in terms of air pressure, temperature, and flow rate. The secondary air system that supplies cooling air to the turbine section is characterized by the conditions present within the turbine disk cavity region in terms of air pressure, temperature, flow rate, and also turbine disk rotational speed.

Through this attention to the necessary rig operating performance characteristics, the non-dimensionalized fluid mechanics parameters are brought to similar levels as in a real world engine. For instance, the air density ratio as measured between main gaspath airflow and secondary airflow (primarily a function of pressure and temperature) are in a similar range of around 2. This parameter directly impacts the sizing of the compressors (supplying air pressure), heaters (heating the main gas path), and chillers (cooling the secondary air). These air conditions and the following appropriate rig and equipment design resulted in properly scaled parameters and a test section analogous to typical engine conditions.

2.3.3.2 Rig Mechanical Design and Function

The basic function and operation of the START Rig will be described briefly here, followed by a discussion of the test section equipment. Outdoor atmospheric air is first pulled into the rig by two centrifugal compressors that then discharge directing the combined flow towards the main turbine test section, after which the air flow is exhausted back outdoors to atmosphere.

Upon exiting the two compressors, the air flow is thermally conditioned. Both the main gas path air flow temperature (which is raised in the heater chamber) and the secondary path air temperature, which is split off prior to the heater chamber (then lowered in temperature in the chiller/heat exchanger), are thermally conditioned at this stage. The rig also includes a series of valves that are used within the air piping circuit to control the air flow rate and pressure passing through each component. Precision flow control valves operate with relatively slow actuation to manage the primary air exchange process during normal testing operation. A settling chamber is located between the main gas path heater chamber and the turbine test section in order to ensure the air flow pressure and temperature are spatially mixed and uniform prior to the air flow entering the test turbine.

Air flow rate is measured as it passes into the turbine through the main gas path and each secondary cooling air path. It is also measured when combined upon exiting the turbine. The turbine shaft power and speed are measured using a torque meter and a dynamometer that are coupled to the end of the turbine shaft. The cooling equipment and dynamometer water system components located outdoors serve primarily to reject the large heat load from the rig to atmosphere. A solid model view and photograph of the turbine room are shown in ***Figure 2-13*** and ***2-14*** that provide context to the physical scale of the rig components and their arrangement, including integrated instrumentation and data systems that will be described in the next report section.

Figure 2-13. *Solid Model Rendering of the Turbine Test Rig Within the START Facility. Image credit: PSU*

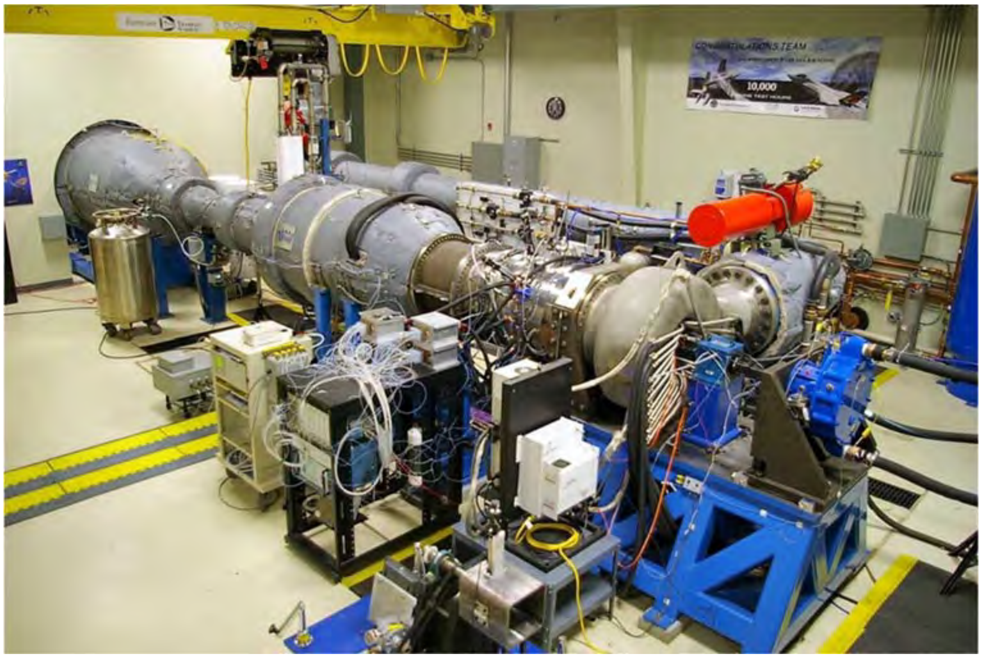

Figure 2-14. *An Overview Photograph of the Turbine Room Taken During the Testing Campaigns Showing the Rig and Many of the Test Section Components Including Instrumentation Systems. Image credit: PSU*

2.3.3.3 Turbine Test Section

The primary test section of the START rig includes a single stage turbine consisting of one row of stationary vanes followed by one row of rotating blades. The rotating assembly is characterized by an overhung turbine including the disk and blades that are mounted towards the upstream end of the shaft.

The bearing structure and table consist of relatively thick and heavy metal components that serve to provide stiff and rigid supports to the rotating turbine assembly. The two main bearings are located at the forward end of the rotor shaft and at the aft end of the rotor shaft. The two bearings operate using magnets that levitate the main shaft in the radial direction approximately 0.010 inch such that a zero-friction and contactless boundary condition is established for the turbine rotor. The zero-friction operation of the shaft during testing increases the accuracy of determining the true lossless power generation of the turbine rotor system. The magnetic bearing system also includes high frequency response sensors that are used to monitor shaft speed and control shaft position. The position sensors can detect shaft position to within less than 0.001 inch at all speeds. Additionally, the magnetic bearings are actively tunable that allow the user to adjust the stiffness and damping associated with shaft vibration and rotor dynamics, which was performed for the current test program to ensure any critical speeds and vibrational modes were safely managed.

After passing through the turbine test section, the air flow enters a downstream settling chamber in which the air flow passes through a baffle system and is then directed towards the rig downstream Venturi meter and exhaust system.

2.3.3.4 Controls and Safety

The design of the START facility and rig was performed with the safety of the personnel and hardware in the absolute highest priority. The safety plan that was ultimately developed was designed and thoroughly reviewed by the Penn State START team, the P&W CLEEN II team, and the P&W engineering test and safety teams. Safety precautions included simple limitations on personnel, such as the prohibition of personnel to be in the test room when the rig is rotating, as well as two-person sign-off procedures to ensure that any inspection or assembly activities had been performed correctly.

To further protect the turbine hardware during testing, certain operational limits to the test turbine and rig equipment were first identified and then incorporated into an advanced programmable logic control (PLC) computer system that is used during all operation and designed to trigger an emergency shutdown should a critical parameter stray from its safe operating range. Some examples of the primary operational safety limits related to the test turbine itself include the turbine shaft speed, torque, position, and axial force load. Other examples of monitored parameters include those critical to the function of the supporting equipment, such as coolers, chillers, water pumps, etc. A suite of instrumentation sensors is used to actively monitor the critical safety parameters continuously in real time at high frequency responses (kHz).

2.3.4 Instrumentation

Because the START facility operates on a steady, continuous-operation principle, it is critical that the test section reaches a thermally saturated, steady-state condition to ensure thermal boundary conditions are repeatable for test operations and to reduce measurement variability in aero efficiency and durability tests. To determine when a thermally saturated state is achieved during rig testing, a series of efficiency measurements were collected during the shakedown process. During these tests, temperatures near the outer diameter wall at the turbine inlet plane, on the outer skin of the test section hardware, and other locations of interest (defined in ***Figure 2-15***(a)) were recorded versus time. Using these data, an assessment of the startup time required to thermally saturate the rig was defined such that the temperature measurement T-P1-R2 (shown in ***Figure 2-15***(b)) exhibits a temperature change of less than 1°R/min.

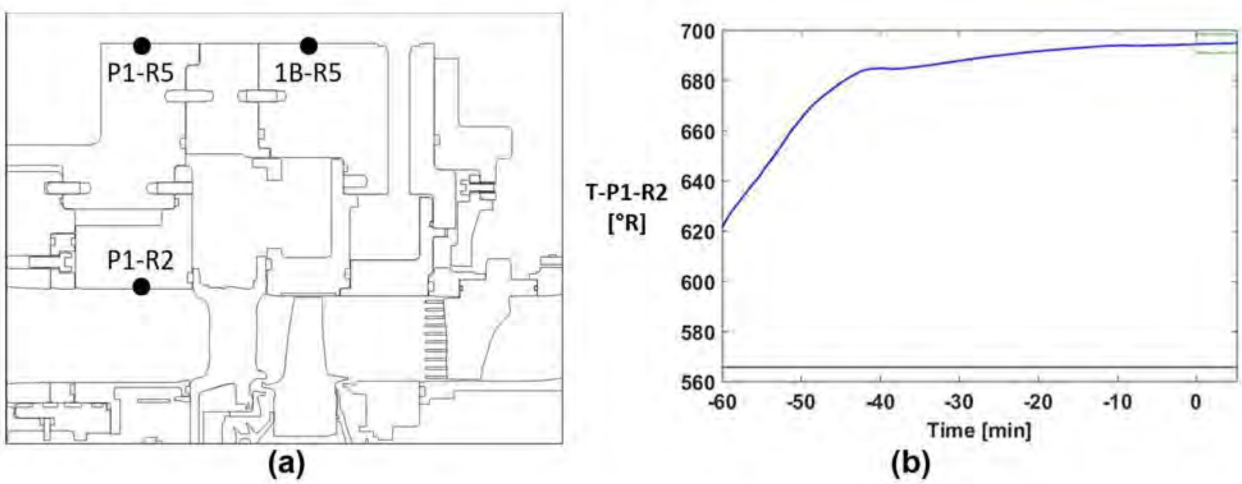

Figure 2-15. *Thermal Soak Criteria Definition*

(a) primary monitor locations; (b) Example time history for temperature monitor location P1-R2, the test period begins at time zero, and the duration of the specified test point is identified by the boxed time interval

2.3.4.1 Efficiency Instrumentation

Turbine efficiency measurements were characterized using stage inlet and exit parameters. Inlet parameters were measured upstream of the vane, and stage exit parameters are measured by a state-of-the-art 360-degree circumferential traversing system downstream of the blades. For program tests that did not require efficiency measurements, the stage exit rakes were removed. In that case, stage parameters, such as stage total pressure ratio, were calculated from a fixed-probe measurement downstream of the blade.

2.3.4.1.1 Turbine Inlet Measurements

Stage-inlet measurements were characterized using six circumferentially distributed exposed bead Type E thermocouples in fixed locations at the midspan upstream of the vane. These thermocouple probes were calibrated using an end-to-end approach maintaining standard wire and channel connections from typical test configurations. Through this wire calibration process, temperature measurement accuracy better than 0.1°R was achieved. Total-pressure probes with 0.125-in. Kiels were equally spaced at the location, however offset from the temperature probes by 30 degrees in the circumferential direction.

These six fixed thermocouples positioned at mid-span provide an understanding of circumferential total temperature variations around the inlet of the turbine test section. A representative example of circumferential temperature variation at the inlet is presented in ***Figure 2-16***(a). In ***Figure 2-16***(a), the temperatures at the aerodynamic design point (ADP) conditions are shown as a difference relative to the arithmetic mean. The measured temperature distortion is highly repeatable and represents the influence of natural convection cooling around the test section. As shown in ***Figure 2-16***, the circumferential temperature distortion is within ±1°R (approximately 0.1% of the ADP set point of 750°R). At elevated Durability Design Point (DDP) temperatures, the distortion is approximately ±1.6°R, or 0.2% of the DDP set point of 860°R.

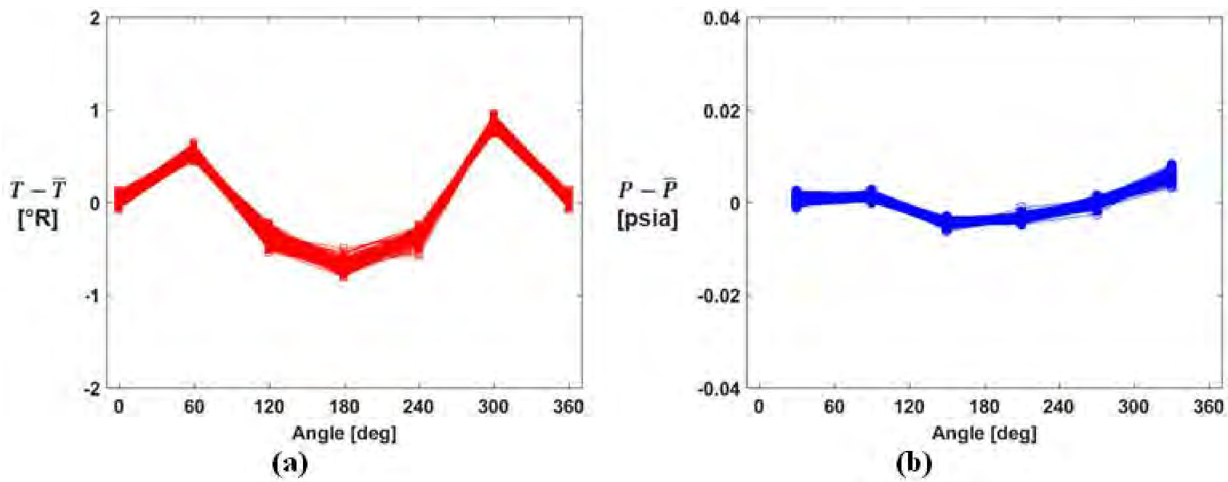

Figure 2-16. *Representative Circumferential Variation of Turbine Inlet Conditions Relative to the Mean at Upstream Plane P0 for ADP Operation: (a) Total Temperature; (b) Total Pressure.*

Similarly, the circumferential distortion of total pressure for the upstream measurement location is shown in ***Figure 2-16***(b). The maximum pressure distortion is shown to be within ±0.007 psia (approximately 0.02% of the ADP setpoint of 41 psia; approximately half of the uncertainty for the pressure measurement itself). Finally, the circumferential pressure distortion was found to be unaffected by temperature increases introduced for DDP operation.

In addition to the midspan inlet measurements, radial profiles of total pressure and total temperature were collected upstream of the vane. Radial profiles of pressure were collected using a United Sensor CA-type three- hole cobra probe with 0.028-in. diameter pressure tubes ***Figure 2-17***(a). Total temperature profiles were measured using a custom Kiel probe with an exposed 28 AWG Type E thermocouple wire (***Figure 2-17***(b)). Representative temperature and pressure profiles for the ADP test condition are shown in ***Figure 2-18***. Here, the experimental measurement points are identified by filled circles. Ultimately, the radial profiles were synchronized with the circumferential measurements of the fixed inlet probes at midspan. It is worth noting that using only midspan data at the inlet rather than the integrated radial profile leads to an over-prediction of stage efficiency.

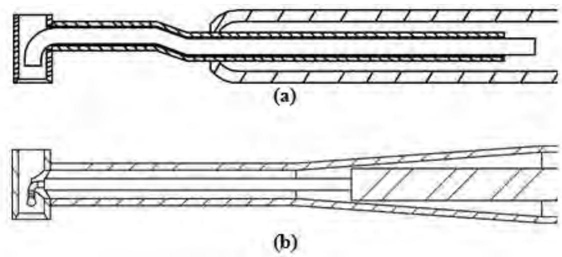

Figure 2-17. *Radial Traversing Probe Designs: (a) Total Pressure Probe; (b) Total Temperature Probe*

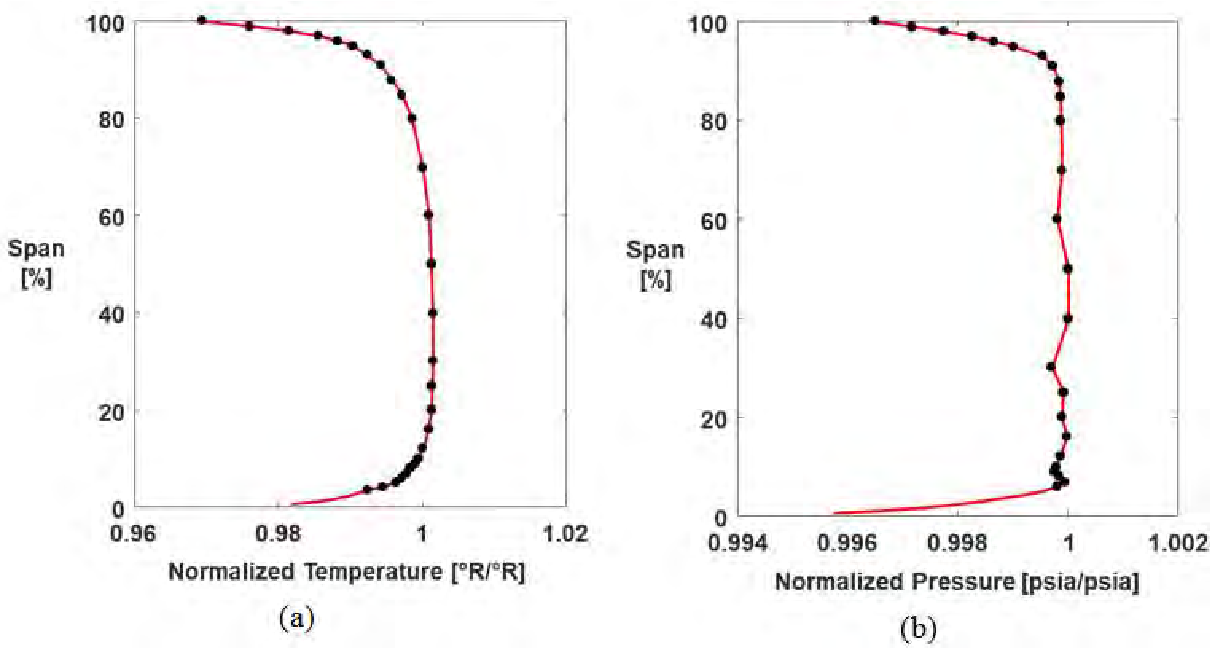

Figure 2-18. *Radial Profiles of Turbine Stage Inlet Parameters at ADP Condition: (a) Total Temperature Profile; (b) Total Pressure Profile*

Additional turbine inlet parameters were characterized using measurements of turbulence intensity with a constant temperature anemometry (CTA) system. Turbulence intensity (TI), is defined using Equation 1, for velocity V, average velocity $\overline{V}$, and fluctuating velocity component, v'.

$$TI=\frac{v'}{\overline{V}}$$

$$V=\overline{V}+v'$$

Equation 1

A TSI hot-film probe with a 0.002-in. diameter sensing element was positioned at midspan upstream of the vane. CTA bridge circuitry was completed using a TSI IFA-100, and frequency response of the system was estimated to be 60 kHz using a square-wave response test. Through this technique, the turbulence intensity was calculated to be 2.4% for a bandwidth up to 20 kHz at operating conditions representative of the current test program.

2.3.4.1.2 Turbine Exit Measurements (360 Degree Traverse)

The Turbine Exit Measurements used for aero-efficiency calculations on the START rig feature a unique, state-of-the-art rotating piece of equipment referred to as the *360 degree traverse*. Many rig-test arrangements employ a set of fixed locations for stationary pressure and temperature rakes. In contrast, the 360 degree traverse allows for unprecedented data gathering of the full circumference of turbine exit duct. What will follow is a brief review of the instruments followed by a discussion of the rotating equipment.

Exit Rake Design

Turbine stage exit conditions were measured using a set of four rakes with equally-distributed Kiels: one 10-element total pressure rake (Pt-10), one 10-element total-temperature rake (Tt-10), one 9-element total-pressure rake (Pt-9), and one 9-element total pressure rake (Tt-9). The rakes of similar types (i.e., Pt-10 and Pt-9; Tt-10 and Tt-9) were installed opposing each other 180 degrees apart. The radial placements of Kiels are arranged such that the Kiels from similar rake types (i.e., both total pressure rakes) alternate span-wise locations to provide maximum spatial resolution once the data from each rake are combined. This arrangement is akin to two combs with the same tooth spacing, but radially offset from each other by half the tooth spacing. The radial placements of the rake Kiels are outlined in ***Table 2-2***.

Table 2-2. *Stage Exit Rake Kiel Measurement Locations (% Span)*

Kiel ID	***Pt-10 or Tt-10 [% Span]***	***Pt-9 or Tt-9 [% Span]***
1	5	10
2	15	20
3	25	30
4	35	40
5	45	50
6	55	60
7	65	70
8	75	80
9	85	90
10	95	-

Each kielhead has a unique angle (see ***Figure 2-19***) associated with its spanwise position. These angles were chosen to follow the CFD-predicted flow angles at the measurement-plane location. It is important to note that, due to the nature of Kiel-probe designs, the pressure and temperature measurements are insensitive to off-incidence flow angles between -20 and +20 degrees.

360 Degree Traverse Rotating Equipment

The 360-degree traverse system represents a collaborative design effort integrating resources from P&W PSU, and Belcan Engineering. In principle, the system operates with the aforementionedfour fixed rakes (i.e. ***Figure 2-19***) equally spaced at 90-degree intervals. Each temperature rake has a dedicatedmulti-cable assembly (two thermocouple cables in total) egressing Type-E thermocouple wires. Each pressure raketerminates flexible tubing to channels of a Kulite KMPS-4 miniature digital pressure scanner (two 16-channel modules, one dedicated to each rake; additional pressure ports are reserved for other traverse-related pressure not connected

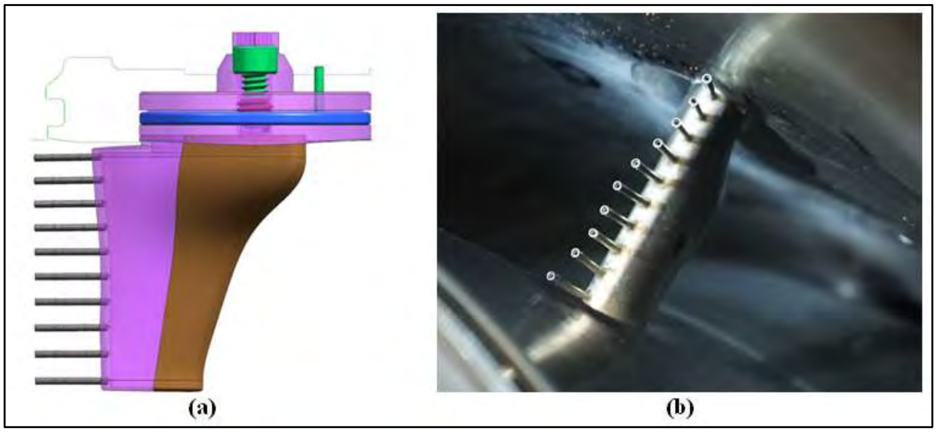

Figure 2-19. *Turbine Stage Exit Measurement Rake*
This view also shows noticeable probe angle changes with span

to rake hardware). Signals from the KMPS module egress from the traverse hardware using one Ethernet cable, including Power Over Ethernet (PoE) provisions to power the device.

To facilitate egress of these wires during the rotational motion of the traverse system, a series of auto-retraction cable housings were designed. These auto-retraction devices use power springs to rewind the cables onto their respective cable coil components. In total, there were three wire-retraction housings to accommodate each egress cable (two multi-channel thermocouple cables and one Ethernet cable for the pressure scanner).

The motion of the traverse assembly through 360 degrees was provided using a stepper motor driving a pinion gear. A belt connected the pinion gear to a large drive gear encompassing the entire traverse assembly. Through this design, the traverse ring to which the rakes are mounted moves, whereas all other surrounding components are stationary. Belt tensioning devices ensured contact is maintained between the pinion and the drive gear. An encoder attached to the common motor drive shaft provided real time feedback of the traverse ring position.

A variety of Kapton-insulated wires (for thermocouples) and PTFE tubing (for pressure rakes) were used with in the housing to facilitate egress.

For the thermocouple rakes, the 0.040-in. MgO thermocouple wires transitioned to Kapton-insulated wires for flexibility. The high quantity of wiring and pressure tubing, thermocouple connectors, and placement of pressure scanner modules all required significant wire and tube management to ensure measurement integrity without damage to equipment. ***Figure 2-20*** highlights the access requirements and distribution of these wires and tubes in the internal traverse cavity.

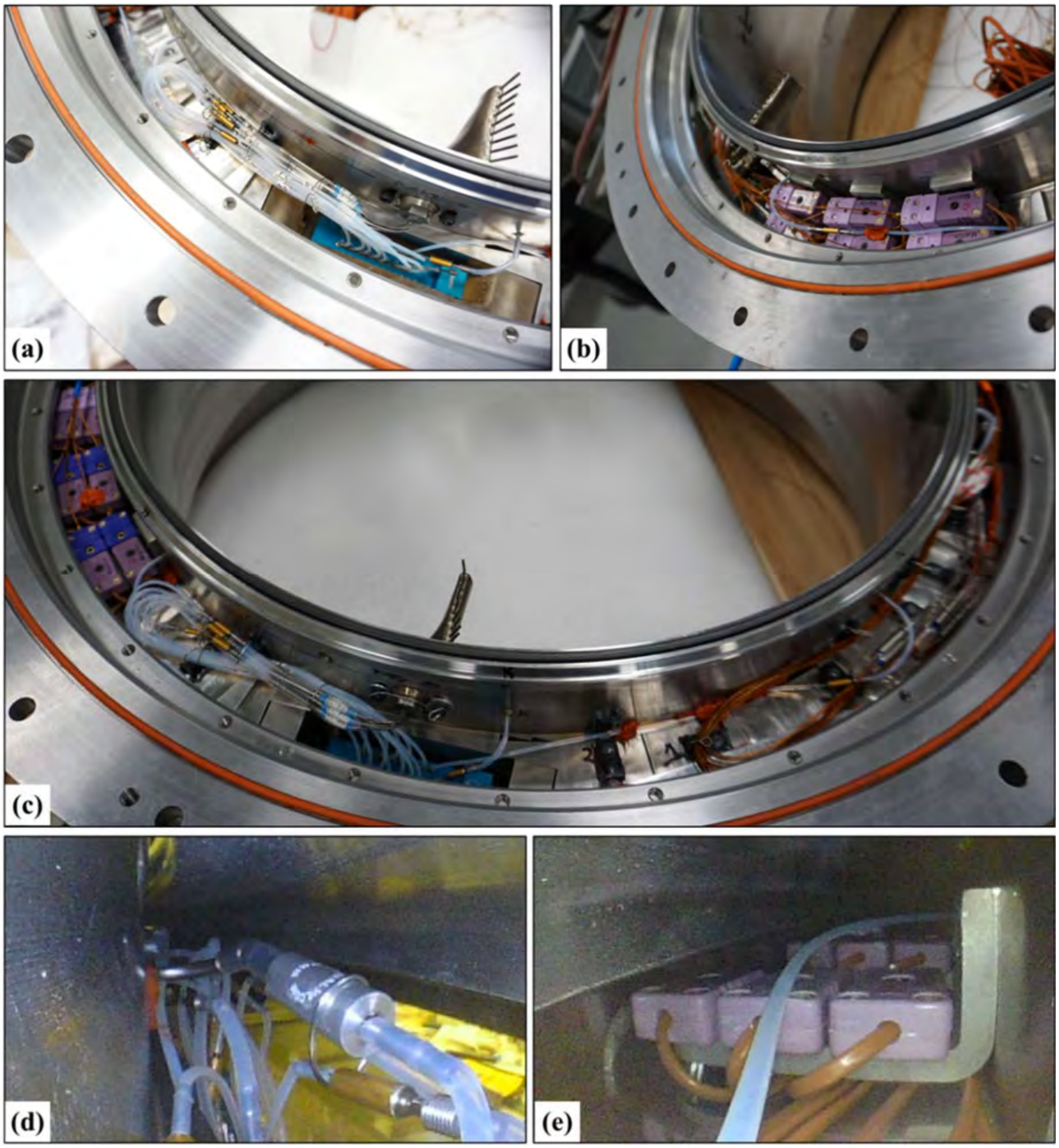

Figure 2-20. *Internal Wire and Tube Management for Turbine Exit Traverse Assembly*
(a-c) View With Open Assembly; (d-e) Borescope Photos of Closed Assembly

As the internal diameter of the 360 degree traverse shared its wall section with the OD of the main gas path test section, steps were taken to ensure thermal protection of the equipment in the traverse. This included selection of equipment for its temperature capabilities, mounting components with a gap between instrumentation/wiring and the wall of the traverse cavity, and providing compressed cooling air (shop air) into the internal cavity during testing (see ***Figure 2-21***).

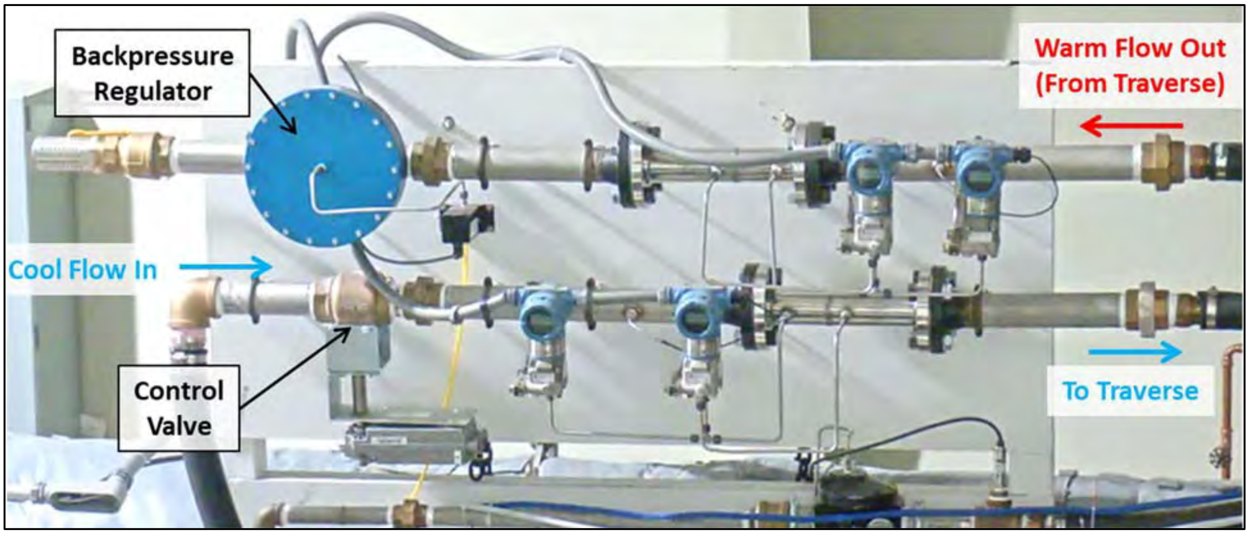

Figure 2-21. *Traverse Cooling Air System*

2.3.4.1.3 Additional Information to Support Efficiency Measurements

Blade tip clearances were measured using a turnkey Capacisense system. This system has a 400 kHz bandwidth, though it was operated with a 200 kHz bandwidth due to magnetic bearing noise. A custom probe that accepts the threaded capacitance sensor was designed to accommodate the thermal growth of the BOAS and case. Four probes were placed in the BOAS, circumferentially located at 3 deg, 99 deg, 183 deg, and 279 deg clockwise from TDC aft-looking-forward. A 0.001-in. tip clearance measurement resolution is achieved with this system. The custom probe and spring assembly is shown in ***Figure 2-22***.

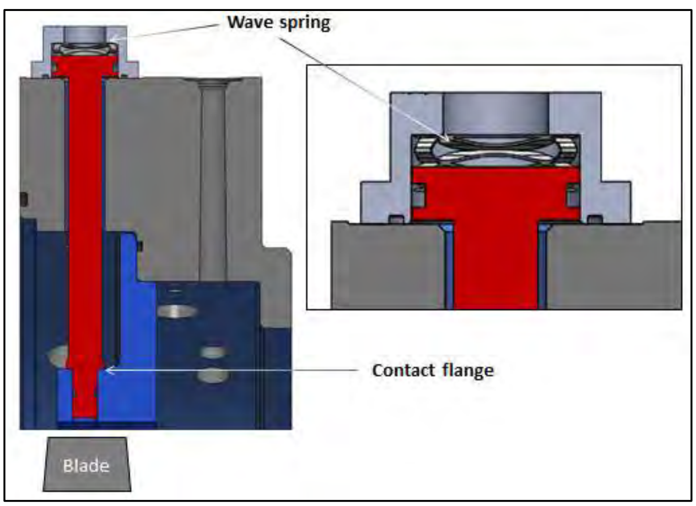

Figure 2-22. *Custom Probe Assembly, Shown in Red, Which Accepts Threaded Sensors*

In order to verify the correct pressure distribution on the vane airfoil surfaces, four vanes were additively manufactured to include internal passages for surface static pressure measurement. Pressure and temperature instrumentation in the vane cavities and upstream of the TOBI allowed for measure the supply conditions of the cooling flows required to calculate the mixed efficiency defined in Section 2.6.3.2.

2.3.4.2 Durability Instrumentation

The selected detector for IR measurements was similar to a camera previously used by P&W so it was possible to leverage some of the learning from that program for thenew START rig instrumentation.

The FAA-CLEEN II program had several IR-related advancements relative to previous engine programs, which included:

1. Improved position accuracy through better rotor shaft indicators
2. Ability to rotate probes for different targets
3. Ability to raise and lower probes
4. Reuse of same probes in multiple locations.

In essence, the IR camera attaches to the rig and accesses the test section where it is able to take several images of the pressure side (P/S) of the turbine blades while running. As noted above, it is movable to allow image capture of different regions of the blades, so that thermal data for nearly the entire surface may be compiled.

Additively Manufactured Vane Doublets

A modified vane doublet to accommodate the IR probe was additively manufactured. This IR doublet is located at top dead center. P&W's Turbine Durability and Aerodynamics groups performed the bulk of the doublet design and came up with a solution that preserves the total flow through the doublet with minimal disruption to the vane aerodynamics. This was in part accomplished by thickening the vane which housed the IR probe while the adjacent vane was thinned.

IR Shakedown Testing

A spin rig was created to be used for preliminary testing of various instrumentation applications before final execution in the START rig. The rig consists of an electric motor driving a shaft connected to an aluminum bladed disk used to simulate turbine blade passing. This spin rig was used to shakedown the synchronization of the IR camera with the once-per-revolution laser tachometer to produce phase-locked images at rotational speeds up to 6,500 rpm. Paint dots were applied to the blade portions in order to study the effect of rotational speed and camera integration time on image blurring. Several more disks were also used to study IR camera performance on even higher linear speeds, properly simulating rig conditions.

2.3.4.2.1 IR Camera Measurements

The amount of radiant energy collected by an IR detector is affected by both the surface temperature and the background temperature. The impact of the background temperature may be minimized by maximizing the emissivity of the blade surface.

When adding a coating to the blade surface, both the radiative heat transfer and conductive heat transfer can be affected. A coating on the surface can in some cases act as an insulator, increasing the blade surface temperature. This effect was quantified during calibration and that the coating procedure had minimal impact on a blade's internal cooling operation.

A need for contrasting features on the blade was identified for the 2D-to-3D image mapping process which was achieved by using a low-emissivity metallic paint without affecting the aero-thermal performance of the blades.

The infrared camera was calibrated using a bench-top setup, before inserting the camera into the START rig. This involved the use of a plate with embedded thermocouples and in the same high emissivity coating as the blades, which could be used to correlate IR images to directly measured temperatures. This calibration ensured a very high degree of precision in the thermal data that was gathered during testing.

2.3.4.3 Instrument Calibration

Thermocouple wire calibration is performed with an oil bath with a temperature stability of better than +/- 0.03°F. The reference sensor is a platinum resistance thermometer (PRT) and is measured by a thermometer read-out. The manufacturer's stated uncertainty for this PRT at the tested temperature is +/- 0.03°F which includes uncertainty due to 100 hour drift and three thermal cycles from the min-to-max temperature range for hysteresis effects.

An aerodynamic recovery calibration was performed. A total of 12 Mach calibrations and one yaw calibration were performed for the temperature rakes at room temperature conditions. A single yaw calibration was performed for the pressure rakes.

Pressure devices are calibrated against a reference pressure generated by a pneumatic pressure controller. The Scanivalve pressure modules have a built in CALZ command which is used at least once per day to perform a zero offset calibration. Calibration of these Scanivalve modules are conventionally performed using the built in calibration ports.

The Kulite Miniature Pressure Scanner (KMPS) that measures the exit traverse pressures is calibrated in a two-step process. The KMPS is first calibrated in increments at room temperature in order to adjust the gain value of each sensor. The second step of the calibration is to account for measurement sensitivity due to temperature effects.

Capacitance tip clearance probes were calibrated using the actual test rotor on PSU's balance machine. The tip clearance probe was mounted onto a traverse system in order to determine the true axial position of the probe relative to the blade leading edge and also to define the zero position of the probe tip to the blade tip, i.e. when the probe head is in contact with the blade tip. Typical calibration variability is less than 0.001 inches. Probes are calibrated with their respective tri-axial cable, coaxial cable, and oscillator and demodulator setup.

2.3.4.4 Data Acquisition

Rig operation, facility monitoring, and primary data acquisition is performed with LabVIEW. The LabVIEW front panels are divided into three screens dedicated to traverse controls, facility monitoring, and test section monitoring and cooling flow control. These three panels are updated to the facility operator effectively at 1 Hz. Voltage signals, thermocouple signals, and pressure signals, are sampled at rates from a few Hz to a few kHz. These sample rates are optimized to balance multiplexing rates, device accuracies, and samples counts with overall refresh rates for the main LabVIEW application.

After the START rig has achieved *steady state* conditions at the operating point of interest, data is acquired for approximately 1 minute. This 1-minute length of data is then averaged together to produce a single data point for each piece of instrumentation. This single data point, which represents the average value across the 1 minute of data acquisition, is used for post-processing operations and efficiency calculations.

2.4 TEST ARTICLE DESIGN AND FABRICATION

2.4.1 Overview and Casting Process

The purposes of the CLEEN II program were to advance the technologies for better fuel efficiencies in the turbine portion of an engine. The GTF engine series was selected as the baseline test bed with the expectation that new technology advancements achieved in this program would be useful in future engines of this model line. As such, the blades used for baseline comparison testing were actual production blades for this engine. The new technologies were incorporated into the specially made technology, or tech blades.

As the baseline blades were sourced directly from the production blade program and their performance has been well documented in numerous hours of actual on-wing flight time, details will not be given in this section regarding the design considerations or manufacturing processes for these blades. This section will instead focus on the design of the tech blades, how they differ from the baseline blades, and the manufacturing of these new specialty blades for the CLEEN II program.

The FAA CLEEN technology blade introduces significant design changes relative to the baseline production HPT first blade to improve thermal and aerodynamic performance. These design features include leading-edge, pressure- and suction-side skin cores for a multi-wall internal cooling geometry, tip-vortex control via tip bowing, multiple tip-surface squealer pockets, and reduced cooling-hole count for reduced Electric-Discharge Machining (EDM) costs.

The blades were cast by P&W's Rapid Prototype Casting Lab (RPCL) in East Hartford, Connecticut, using advanced technology ceramic cores. Throughout the various steps of development of this blade, learning was attained for how to properly cast advanced airfoils. Learning from this development program was directly transferred to future HPT blade designs.

2.4.2 Core Configurations

The CLEEN tech blade consists of a variety of internal cooling feature configurations for a rainbow wheel of testing. It should be noted that the external shape of all the tech blades was common. The first batch of castings produced does not have crossovers between core passages. The last batch of castings produced possess six crossovers between the 2nd and 3rd pass of the serpentine core passages. The crossovers were intended to re-energize the OD cavity where the cavity is was starved of flow due to core manufacturing non-conformances. Again, the blades with these different core con- figurations have the same external shapes, and there is no visual difference between the two when looking at the external surfaces of the parts. The resulting machined blades from these castings then have four coating configurations: blades without coating, blades with primer only, blades with primer and PTFE, and blades with black paint (for IR emissivity). This results in a total of eight different finished machin--ed blade configurations in the turbine disk for testing.

2.4.3 Design Considerations

Aero/Durability optimized designs are aimed at maximizing the use of internal convection and film cooling for increased turbine performance and long life with less cooling flow. Key to the design of the Tech blade was to carry out multi-disciplinary workflows and optimizations that introduce physics-based tools with heat-transfer predictive capability in the aerodynamic design process. The external airfoil loading is shown in ***Figure 2-23***, which can also reduce heat transfer coefficient at the leading edge of the airfoil.

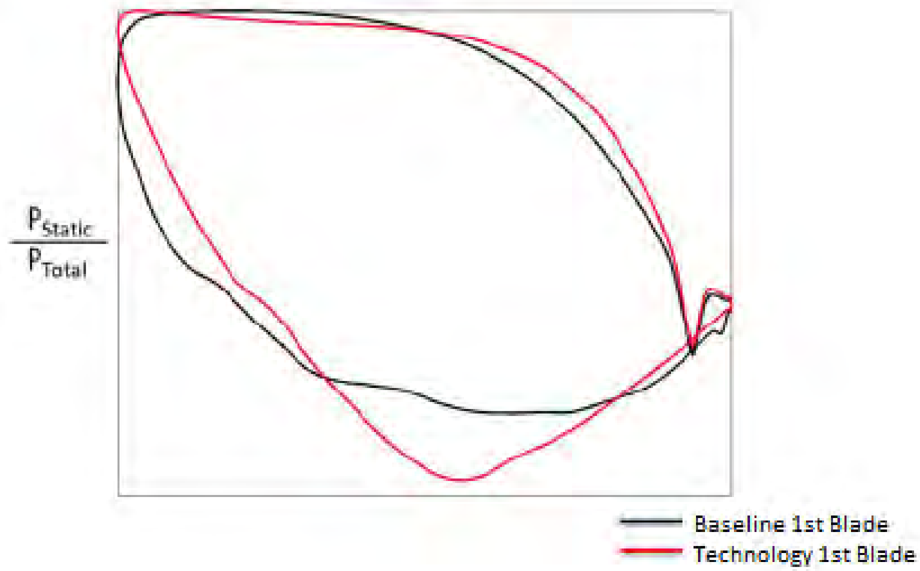

Figure 2-23. *Comparison of Loadings at 50% Span*

Non-axisymmetric endwall contouring (EWC) was applied to the blade-hub flowpath to reduce secondary flow losses.

CFD-predicted radial profiles of total pressure and temperature at the exit plane of the single stage turbine are plotted in ***Figure 2-24***. Profiles are shown for both the baseline and tech blade configurations here. The main differences evidenced by these plots is that the tech blade is predicted to alter the radial profiles more evidently in the outer half of the span than the inner half. In fact, the tech blade radial profiles are predicted to nearly match those of the baseline blade in the inner half of the span.

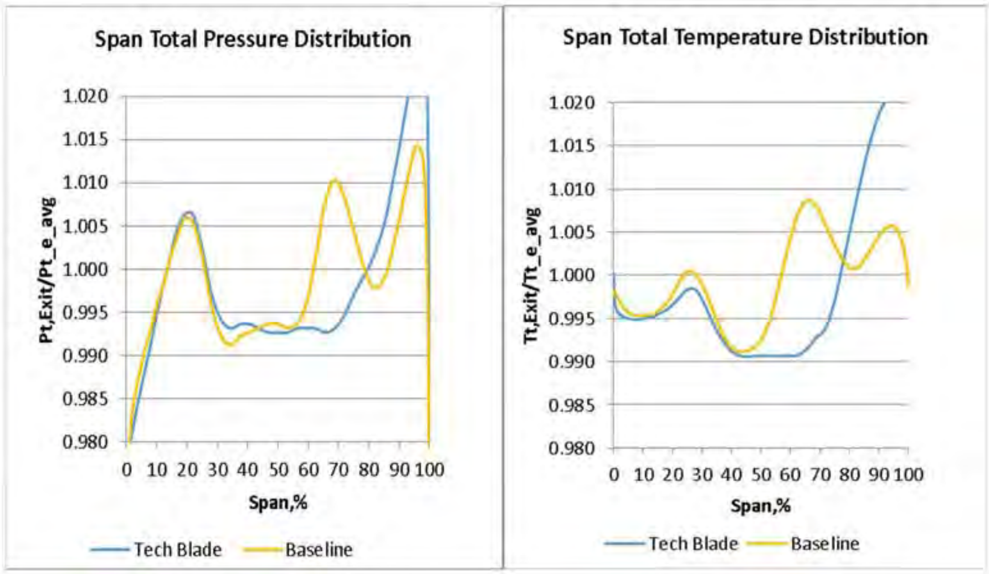

Figure 2-24. *Comparison of Exit Pressure and Temperature Distribution*

2.4.4 Hardware Inspections

Typical inspection methods for multi-wall castings include a combination of CT and ultrasonic (UT) scan techniques. The CT scanning is necessary for the internal locations where the UT probe cannot be used. CT scanning is Computed Tomography — a computer processed combination of x-rays at various angles to produce *virtual slices* through the part. As the tech blade is an atypical double-wall design, CT scan was more appropriate for wall thickness checks and was the primary method used. There were 47 total inspection points, including the leading edge, internal multi-wall, concave side, convex side, and trailing edge inspection points.

Aside from min-wall checks at specified radial sections, full-sweep CT scans were used as well. The full scan allowed the HPT team to view issues like kiss-in, where skin core and internal cores intersect as well as core break, which may not have been detected with the fixed radial sections. Kiss-ins were evident towards the tip of the blade, causing pressure equalization in the individual cores, resulting in deviation from the design intent. Core break, also evident towards the tip, resulted in restriction of flow to exit the tip. The full CT scanning of all hardware allowed the IPT to select the best parts from the group for the rig test as well as allow RPCL to identify areas where additional improvements/adjustments and possibly bumpers (cores positioning features) were needed.

The detail radius of the tip of the blade was designed to match the tip of the baseline rig blades. The baseline rig assets were product relevant development engine blades that were stripped of their metallic and ceramic coatings and were then re-coated with primer or primer and PTFE of various thicknesses, to provide IR capability in the START and maintain similarity to the tech blades. The baseline blades themselves had a tip radius which was a function of machining. This radius was machined from the blades after they were installed in the development rotor, were shimmed out, and then underwent a grinding process for the rotor.

The tech blades were designed to have the same tip radius but did not undergo a grinding process in the rotor. The tech blades were detail ground only, and any variation in sizing in the individual rotor slots added to the machining tolerance variation in each blade that can then impact clearance between the blades and Blade Outer Air Seal (BOAS). Through detailed bench measurements, Penn State verified that, while shimmed in the rig rotor, the tech-blade-tip radii were equivelant to the baseline blades at cold conditions.

Furthermore, the capacitance probes in the START record measurements of the tip clearance between each individual blade in a wheel, and the BOAS. Capacitance probe data for the baseline blades showed that individual blade tip clearances vary by about .003 in. across the baseline blades in the wheel. Given the differences between coated and uncoated blades and the differing thickness of coatings, these variations were expected and also shown to be minimal, illustrating the tight tolerances held during construction of the rig.

2.4.5 Changes from Design Intent

Casting single-crystal airfoils for use in turbine engines is notoriously difficult and it was therefore no surprise that casting the tech blades, a first-time casting for this design, with several brand-new features, presented challenges and delays. Careful attention was paid to the necessary rig-to-engine corrections and additional bookkeeping to discern accurate back-to-back thermal and performance comparisons. These rig-to-engine corrections enable the use of the tech blades to gain useful insights related to future products.

2.5 RIG OPERATION AND TEST EXECUTION

With all necessary equipment becoming available and the necessary preparatory tests and calibrations completed in the latter half of 2019, aero-efficiency testing began in August 2019 with the baseline blade. The IR equipment was then assembled into the rig and the baseline IR tests were completed at the end of the year. A swap was done to install the tech blades, and the IR tests completed in early 2020. This was followed by a change of configuration back to the aero efficiency equipment, and the tech blade aero tests were completed in March of 2020.

Overall, the rig performed very well during the IR testing, so the information in this section will focus on the aero-testing which showed a few issues during the initial tests in August, and then more severe issues in March, which eventually required a repeat of those tests. The executed test program is outlined in ***Table 2-3***, where the efficiency tests are divided into round A (original tests) and B (repeat tests).

Table 2-3. *Executed Test Program*

Test Round	*Blade*	*Test Dates*
Efficiency-A	Baseline	August 2019
IR	Baseline	December 2019
IR	Tech	February 2020
Efficiency-A	Tech	March 2020
Efficiency-B	Tech	August 2020
Efficiency B	Baseline	September 2020

A couple of minor issues presented themselves during the August 2019 baseline blade aero testing. With the 360 degree traverse, data gathering was limited to 350 degrees instead of the full 360-degree sweep. This was quickly remedied by moving limit switch. Additionally, a localized temperature variation was apparent when plotting the temperature data. This was traced to a slightly recessed BOAS cap plug. Both these issues were comparatively minor and were addressed prior to running the efficiency tests for the tech blades in March 2020.

During the first test campaign of the baseline blade in August 2019, data from the 360 degree traverses, visualized as full-annular plots, revealed unexpected, very localized regions of high temperature and pressure near Top-Dead-Center (TDC) (***Figure 2-25***). After conducting a thorough root-cause analysis, it was found that a port for IR camera access port in the BOAS was not plugged in a flush manner (see ***Figure 2-26***). When each rake traversed past this circumferential location, the effective blade tip clearance was increased by up to 0.050" (See ***Figure 2-26***(a)). In addition to this hardware deviation issue, the test team learned that the traverse stop-switch prevented achievement of a full 360 degree traverse. The resulting gaps in data are shown in ***Figure 2-25***. These issues were rectified when the tech blade was run and 2nd test campaign.

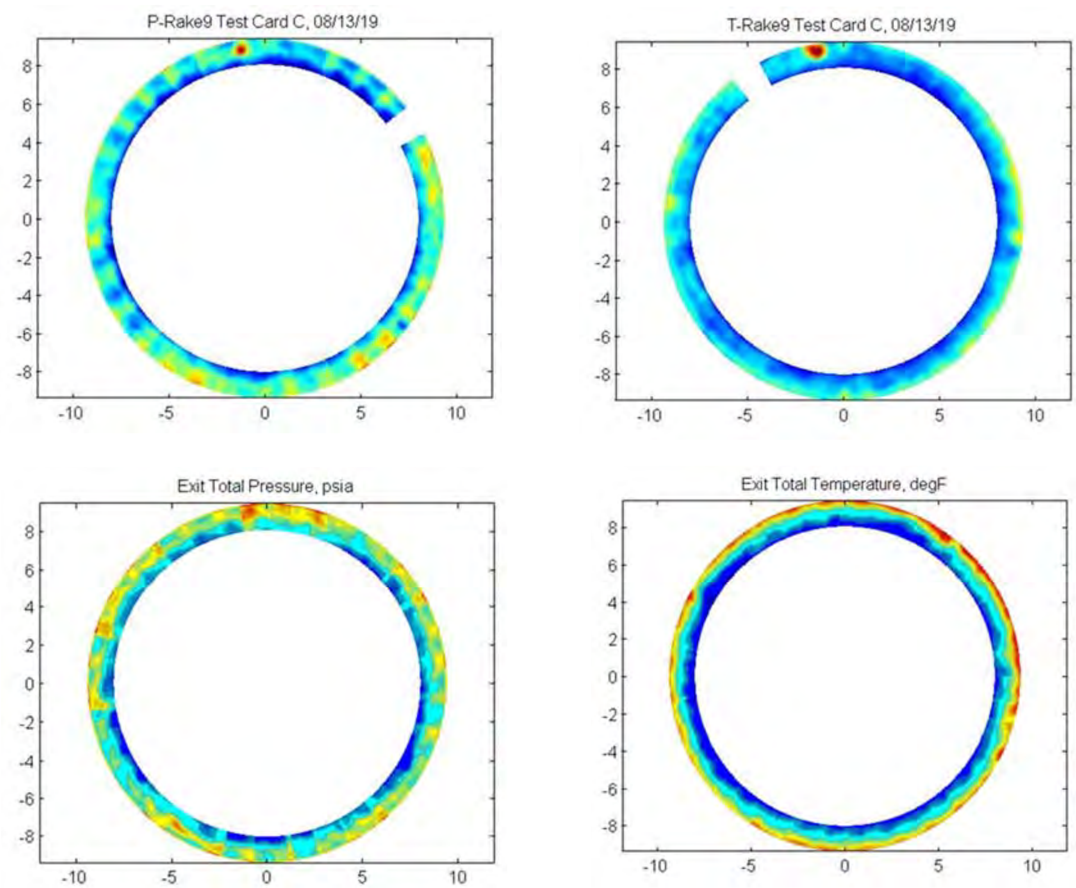

Figure 2-25. *Baseline Traverse 9-point and 10-point Probes Reading Contours*

Figure 2-26. *Thermal Imaging Access Port Plug*
Originally slightly recessed, now shown flush-coated for 1st test campaign tech blade efficiency and subsequent 2nd Test Campaign Baseline Blade and Tech Blade

Just after completion of the tech blade efficiency tests in March 2020, the COVID-19 pandemic caused a shutdown of the START facility for several months. During this time, data processing continued, and it became apparent that there was an issue with some aspects of the rig, causing widely varying efficiency data. The efficiency data had been very stable during the August 2019 test, and within the stated objective of this rig of achieving +/- 0.10% repeatability. The March 2020 tech blade efficiency data showed a much larger amount of variability at +/- 1.38%.

The investigation into what was causing the variation was hampered by the inability to go into the rig to do any tests. However, during the shutdown it was possible to continue scrutinizing the data and eventually the issue was traced to a failing power supply in one of the upstream Scanivalve pressure units (***Figure 2-27***). The START facility was reopened in June 2020 and testing confirmed this hypothesis, with the power supply on this unit drifting significantly throughout the day, indicating a failing piece of hardware (***Figure 2-28***).

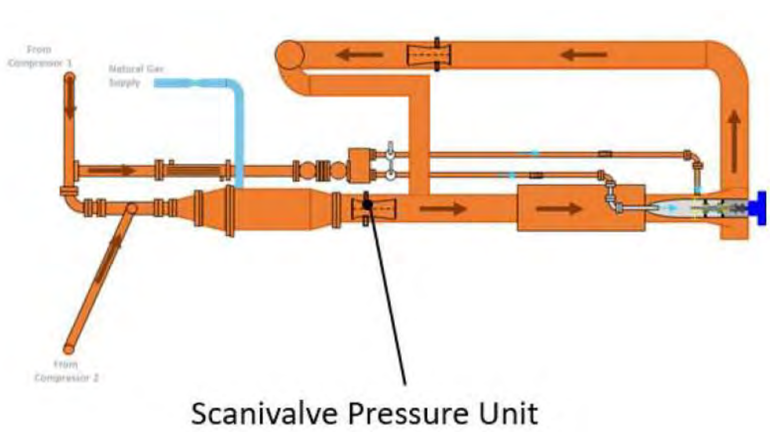

Figure 2-27. *Location of the Scanivalve Pressure Unit — Upstream of the Test Section*

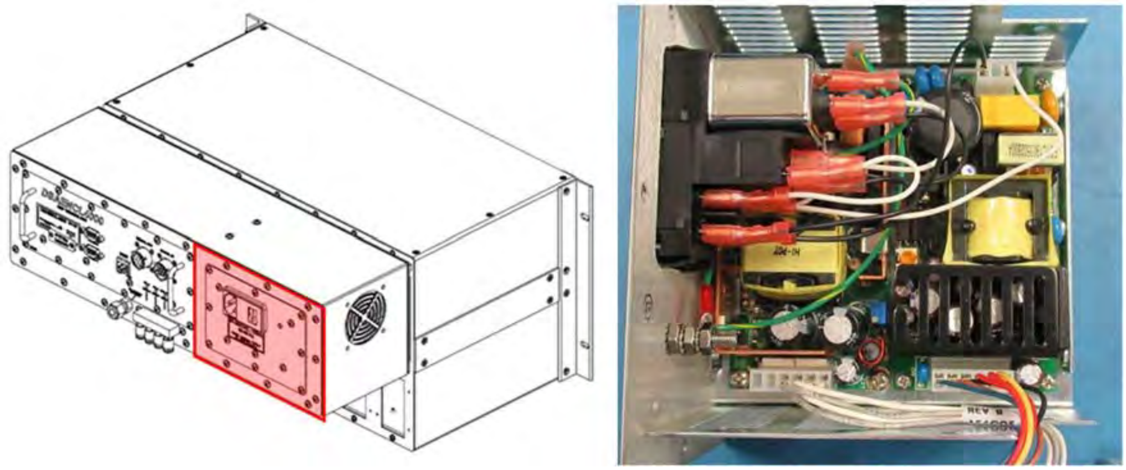

Figure 2-28. *Detail of the Failing Power Supply Hardware Component*

With the issue now known, a plan was developed to repair and upgrade the START facility and complete a set of repeat tests to ensure the best quality aero-efficiency data for the system level performance assessment. Facility repairs were conducted from June through July of 2020, with additional monitoring added as well as procedural changes designed to increase the repeatability further (such as modification to the thermal soaking procedure).

These upgrades were completed at the end of July 2020, and the repeat tests began in early August. The tech blades were already in the rig and so testing began with those blades. At the end of August a swap was done to install the baseline blades back into the rig, and those repeat efficiency tests were completed by the end of September. The new repeat data achieved the goal of improving the quality and repeatability of the efficiency tests, and providing better back-to-back results for assessment. Both tech and baseline blade test now achieved less than +/- .05% variability. More detailed discussion of this and the rest of the results is present in Section 2.6.

2.6 PERFORMANCE TEST RESULTS

2.6.1 Introduction

With completion of turbine and instrumentation design work, hardware fabrication, rig construction activities, and facility/instrumentation shakedown by late 2019, performance testing for the CLEEN II program kicked off in August of that year. Initial testing focused on the baseline blade design. Once the tech blades were available a few months later, they were first used for IR testing, and as such, the tech blade aero testing was scheduled in March, 2020. During March, 2020, an issue was discovered with an instrumentation power supply in the rig, yielding inconsistent test results. Also, at this time the worldwide COVID-19 pandemic caused a temporary shutdown of the rig facilities. After determining the cause of the data issues during the shutdown, the rig was reopened in June, 2020 with a plan to improve the facility and repeat the performance-related tests. The repeat testing was concluded in September, 2020. This repeat testing allowed for an improved back-to-back assessment of stage efficiency for the tech and baseline blades due to improved repeatability and data quality.

2.6.2 Post-Test Hardware Measurements

Part of the process of both the engine-to-rig and design-intent-to-as-cast performance bookkeeping is to incorporate detailed inspection data into the analysis. For aeroefficiency, several types of hardware measurements were performed after testing supported the bookkeeping processes. These measurements included:

1. As-cast CT scanning and CMM measurements of both the airfoil profiles at several spans

2. Measurement of blade flow areas (throat areas of the blades when installed and shimmed to simulate centripetal loading)
3. Measurements of blade-tip radii to support understanding of running clearances.

Most of the inspection measurements were taken after testing was completed in September 2020. Both sets of blades were sent from the PSU START facility back to P&W in Connecticut to undergo flow testing of the internal passages (for durability) as well as CMM measurements. CMM requires the blades to be installed in the disk and shimmed to simulate being under centripetal load. This work was completed and the results were available for integration into the analysis by the end of October 2020.

2.6.3 Performance Testing, Analysis, and Results

2.6.3.1 Test Matrix

The test team made a recommendation of rig running conditions as listed in Table 5.1 after completing rig operability/verification for the proposed test matrix. This was accomplished by varying the Speed Parameter (SP) and Pressure Ratio (PR) by ±5%. Since the facility exhaust duct arrangement limits the downstream static pressure of test section, PR levels more than 5% above ADP could not be achieved. Also, related to the speed parameter variation, the mechanical speed of the magnetic bearing system was limited to approximately 11,000rpm, which limited the maximum achievable values to be just 2% above ADP. As a result, the team decided to extend the lower range of PR and SP variation so that a minimum of three points would be conducted to characterize the shape of the efficiency lapse curves.

2.6.3.2 Pre-test Analysis

The blades were cold flow tested to generate hot flow curves which are used in the secondary flow modeling. CFD analysis was done to estimate the rpm factor between static and rotating hardware. In the flow model of ***Figure 2-43***, the inlet pressure and temperature at the TOBI, purge, Aft Wheel Space (AWS), operating inlet, and vane trailing edge were used as boundary conditions for each test card. In order to better match the flow measured in the rig, the TOBI, purge, and AWS knife-edge (KE) areas were calibrated, which resulted in a representative flow model for each test card measured.

The isentropic turbine efficiency, η, was calculated based on measured mixed-stream mass-flow rates and thermodynamic properties (pressure and temperature) acquired from the 360 degree traversing rakes for the turbine test section control volume.

$$\eta_{th} = \frac{\left(\dot{m}_{main}h_{main} + \sum_i \dot{m}_{TCA_i}h_{TCA_i}\right)_{inlet} - \left(\dot{m}_{main} + \sum_i \dot{m}_{TCA_i}\right)h_{exit}}{\left(\dot{m}_{main}h_{main} + \sum_i \dot{m}_{TCA_i}h_{TCA_i}\right)_{inlet} - \left(\dot{m}_{main}h_{main} + \sum_i \dot{m}_{TCA_i}h_{TCA_i}\right)_{exit,ideal}}$$

Equation 1

Supplementary quantification and validation of turbine efficiency is also available via Equation 1 by replacing the actual work in the numerator of Equation 2 with the extracted power, as measured by the turbine shaft torque meter, τ, and the rotational speed, Ω.

$$\eta_{th} = \frac{\Delta H_{shaft} + \sum_i \Delta H_{TCA,pump_i} + \Delta H_{HPX}}{\left(H_{main} + \sum_i H_{TCA_i}\right)_{inlet} - \left(H_{main} + \sum_i H_{TCA_i}\right)_{exit,ideal}}$$

Equation 2

For the main gas path flow and each individual cooling flow, the measured temperatures and pressures were combined with additional fluid property details to accurately calculate specific total enthalpy, ht. The total enthalpy was determined via a P&W proprietary gas property table. All the efficiency data presented in this test report are based on the P&W data-reduction process.

Similarly, the mass flow rate, $\dot{m}$, for each fluid stream (main gas path and each cooling stream) was calculated using Venturi equations based on ASME-standards MFC 3M and PTC-19.5. The torque-based efficiency formulation in Equation 2 can be directly compared with the thermal efficiency from Equation 1. The torque value for Equation 2 was measured using a Torque-meters, Ltd. phase-shift torque meter with 0.1% full-scale accuracy relative to 516 ft-lbf range. Additionally, redundant torque measurements were also available from a load cell attached to the turbine dynamometer. Shaft rotational speed was measured with a laser tachometer using a once-per-revolution TTL signal converted to operating speed with 0.1 rpm resolution.

Temperatures and pressures acquired from the stage-exit traverse system can be characterized using information from either the 9-point or 10-point measurement rakes, along with the combination of the two rakes. Area-averaged measurements from these independent temperature and pressure rakes are typically within 0.1°R and 0.02 psia of each other. The impact of these variations on integrated efficiency calculations represents ±0.02 percentage points by selecting paired rakes (i.e., Pt-9 and Tt-9 or Pt-10 and Tt-10), but general characterization of overall stage performance is quantified using the arithmetic mean of pressures and temperatures from both rakes. Based on the above accuracy range of individual contributors to the efficiency equation, the uncertainty of efficiency based on measure data is ±0.4%.

2.6.3.3 Test Data

Turbine performance tests were conducted from August 2019 to September 2020 for both the baseline and tech blade configurations. This testing resulted in approximately 50 days of data collection with the conduction of over six-hundred 360 degree performance traverses. As mentioned earlier, the first campaign began with the baseline blade in August, 2019, followed by the tech blade testing in early 2020. The tech blade testing ended abruptly due to the COVID-19 pandemic-related restrictions. Although the quality of these data sets met the quality standards for the CLEEN II test matrix, variations of the BOAS material and differences between first vane leakage levels between the two configurations raised concerns regarding the relevance of the data.[1]

The joint PSU/P&W team made the recommendation to retest after having conducted thorough evaluations of data acquired in this phase. The P&W program office and Validation Discipline recommended repeat testing to minimize uncertainty engendered by hardware issues and cooling-flow differences between the two configurations.

From August to September 2020, the repeat testing for both the tech and baseline blade configurations was more efficiently executed due to learning gained during the earlier testing.

2.6.3.3.1 Exit Traverse

The turbine exit total pressures and total temperatures were measured by 4 different rakes: two total-temperature rakes (9-point and 10-point each) staggered in radial span, 180 degrees apart circumferentially. Likewise, total-pressure rakes were employed with the same arrangement. All four rakes were mounted on a 360 degree traversing mechanism which enabled the recording of the full-annulus flow field for each test condition. ***Figure 2-29*** shows the measured total-temperature profile (Tt vs span), scaled by the average value, for both the baseline and tech blades, at the pseudo aero design point, i.e., Test Card C0 (without vane trailing edge cooling flow).

The data shown here are for the design intent TOBI flow level. One should remember that in this arrangement, the tech blade, which under flows by approximately 20 percent due to manufacturing non-conformances,

[1] Lemmon, E. W., Bell, I.H., Huber, M. L., and McLinden, M. O., 2018, NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties- REFPROP, Version 10.0, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, MD.

drives more front cavity leakage flow into the main-gas path at the ID just upstream of the blade. It is this redistribution of flow that is believed to cause the marked and unexpected reduction in the total-temperature profile in the ID region compared to the baseline blade. This is clearly evidenced in the data shown in ***Figure 2-29*** between 0 and 50 percent span. This trend was not expected based on the design feature differences between the baseline and tech blades.

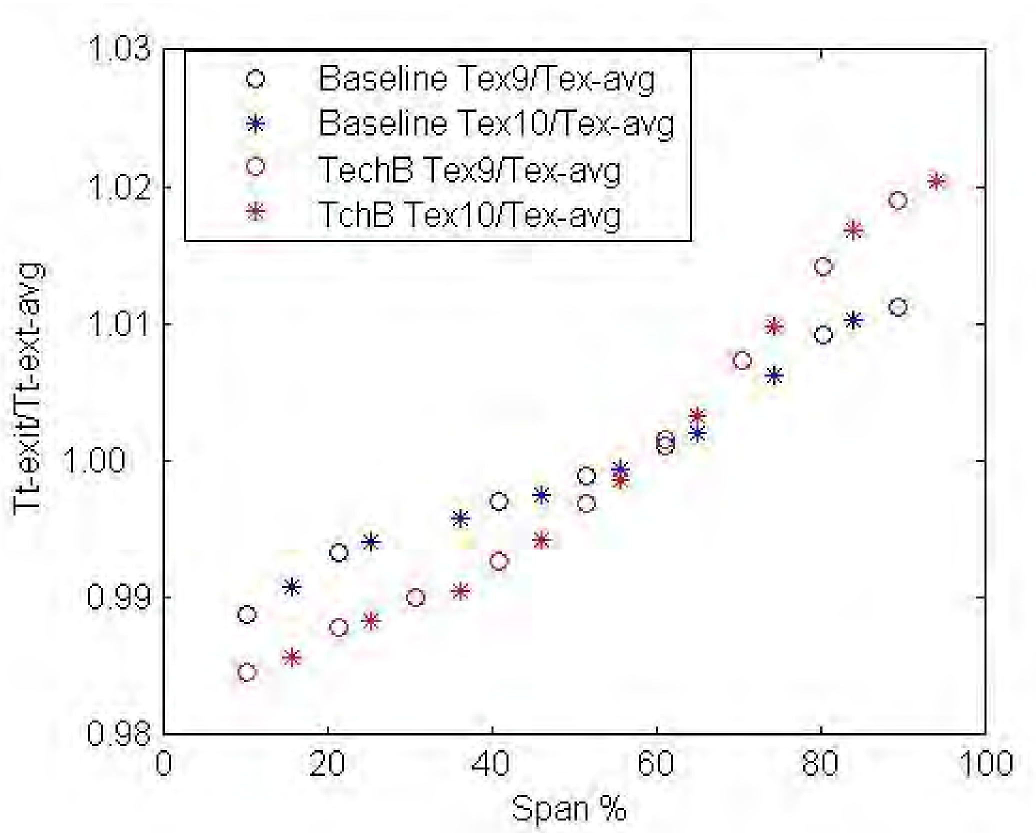

Figure 2-29. *Scaled Turbine-exit Total-temperature Profiles for the Baseline and Tech blade Configurations With Design-intent TOBI-flow Level*

As reviewed earlier, testing was also conducted for both the baseline and tech blades with minimum TOBI flow, i.e., Test Card A4. Similar to the plot shown in ***Figure 2-29***, ***Figure 2-30*** displays the scaled turbine-exit total-temperature profiles with the minimum TOBI flow level. Here, a more sensible (as predicted) result is revealed, whereby the tech blade configuration produces a total temperature profile shape very similar to the baseline in the ID region of the span. This is more in keeping with the aforementioned CFD predictions for these radial profiles.

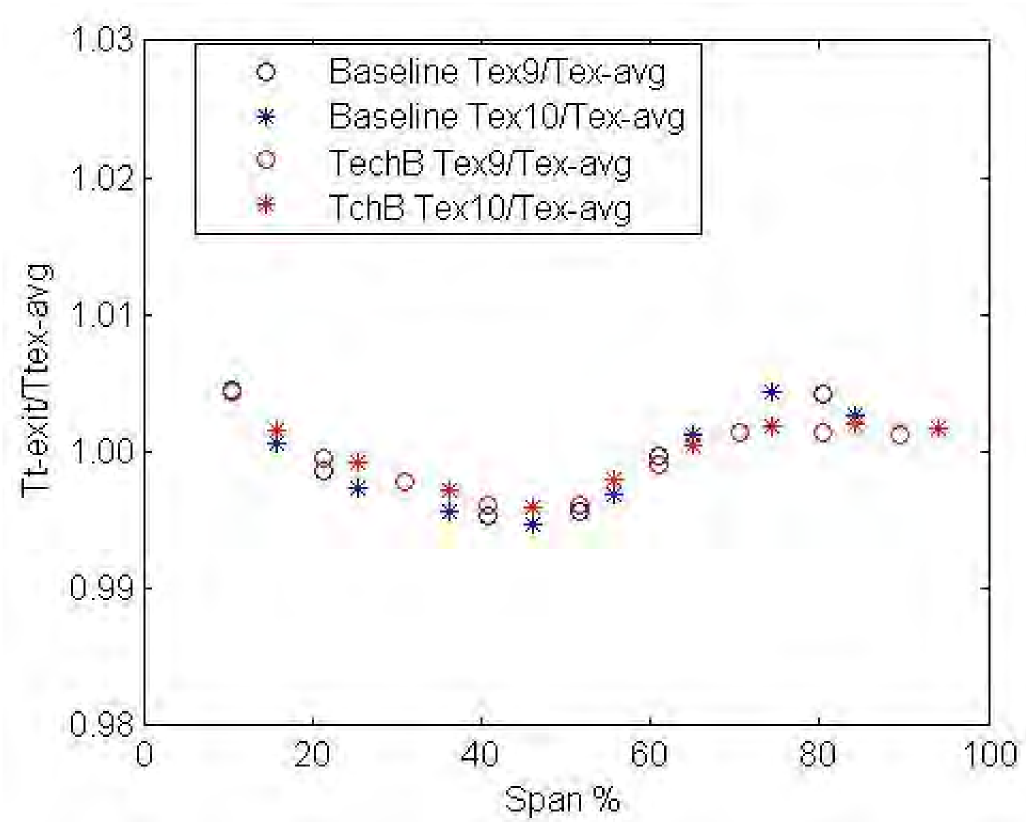

Figure 2-30. *Scaled Turbine-exit Total-temperature Profiles for the Baseline and Tech blade Configurations With Minimum TOBI flow Level*

Figures 2-32 and ***2-31*** show an example of the full-wheel aerodynamic exit traverse data collected for each test point for the baseline blade configuration. Both total temperature and pressure are recorded by the traversing system for the full 360 degrees of the exit duct behind the turbine stage. These data are then area averaged across the entire measurement domain and employed to calculate the pressure ratio and efficiency of the stage. It is worth noting that there are non-negligible variations around the circumference of the exit duct which would not be accurately captured and factored into the efficiency calculation if less than the full 360 degrees was traversed.

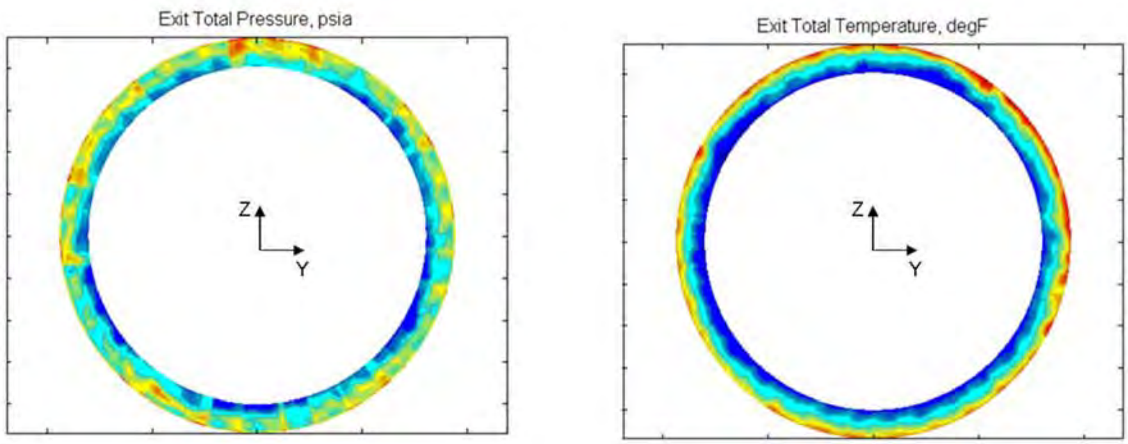

Figure 2-31. *360-degree Exit Total Pressure and Total Temperature Contour (Tech Blade Retest, August 2020)*

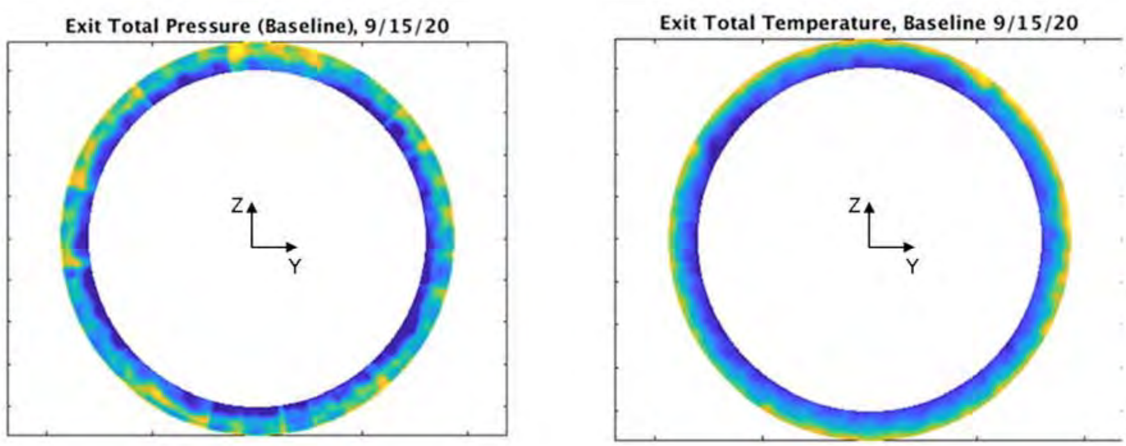

Figure 2-32. *360-degree Exit Total Pressure and Total Temperature Contour (Baseline Retest, Sept 2020)*

Figure 2-31 shows an example of the full-wheel aerodynamic exit traverse data collected for each test point for the tech blade configuration. While the color scales are not precisely the same as the images shown for the baseline blade data, similar variations in the circumferential direction are present and highlight the need to capture the full annular flow field when measuring efficiency in such a rig.

2.6.3.4 Post-Test Analysis

2.6.3.4.1 Comparison With Post-test Analytical Prediction

The measured rig efficiency, as described in the data reduction section, is calculated via a mixed-stream, control volume approach. Following the second, repeat testing campaign, post-test analyses have focused on relating the measured efficiency data from the rig to engine-specific applications.

As mentioned earlier, the under flowing tech blade drove a redistribution of the blade cooling flow supplied by the TOBI. The main effect was that the flow emanating from front cavity upstream of the tech blade was notably increased compared to design intent, while the cooling flow to the main body of the tech blade was reduced relative to design intent.

Because the tech blades were found to be flowing notably less than design intent and lower than the baseline blade, a higher TOBI supply pressure was required to target the same TOBI flow rate. The impact of this higher supply pressure for the TOBI flow in the tech blade testing is two-fold:

1. The ideal work term in the denominator of the mixed-stream efficiency calculation is increased, thereby decreasing the turbine efficiency.
2. The front cavity flow between the vane and blade increased to accommodate the increased TOBI flow. This cavity flow entering the main gas path is more detrimental to efficiency than the main-body cooling flows of the blade.

So, this mal-distribution of TOBI flow, along with the higher supply pressure for the TOBI flow do not represent engine relevant conditions and therefore must be corrected when relating the rig data to an engine application.

When applying relevant corrections to the engine-to-rig efficiency bookkeeping as well as accounting for geometry deviations, the predicted efficiency for the baseline blade configuration is 0.25% lower than the measured efficiency. Following the same methodology, the efficiency prediction for the tech blade in the rig is 0.08% lower than the measured efficiency.

2.6.3.5 Performance-Related Conclusions

A back-to-back comparison of bookkept efficiency levels for the baseline and tech products suggests that the tech blade configuration improves stage efficiency by 0.11% over the baseline blade design. This is in line with expectations of a small efficiency improvement for the tech blade based on pre-test predictions

Key learning from the test campaign includes the recommendation of using individual TOBIs sized separately for each blade configuration (lower flow rate for tech blade with same supply pressure). This would mitigate challenges associated with the bookkeeping required to relate the test data back to product relevance. Additionally, the current 360-degree traversing device blocks access for the installation of a radial-circumferential traversing cobra probe down-stream of the HPT. Rectifying this interference with design changes would allow for use of the cobra probe to collect flow-angle data at the turbine exit to gain.

2.7 DURABILITY TEST RESULTS

2.7.1 Introduction and Background

The CLEEN II program objective set forth to quantify cooling benefit associated with the advanced durability technology in a turbine airfoil. The cooling efficiency of such technology airfoil design was then compared to that of a baseline airfoil design. The baseline airfoil design used herein was representative of a P&W legacy airfoil in current commercial applications. In order to quantify the cooling benefit, the thermal response of the blade i.e. blade temperature, was measured as a function of the cooling air delivered to the airfoil in a controlled turbine rig environment.

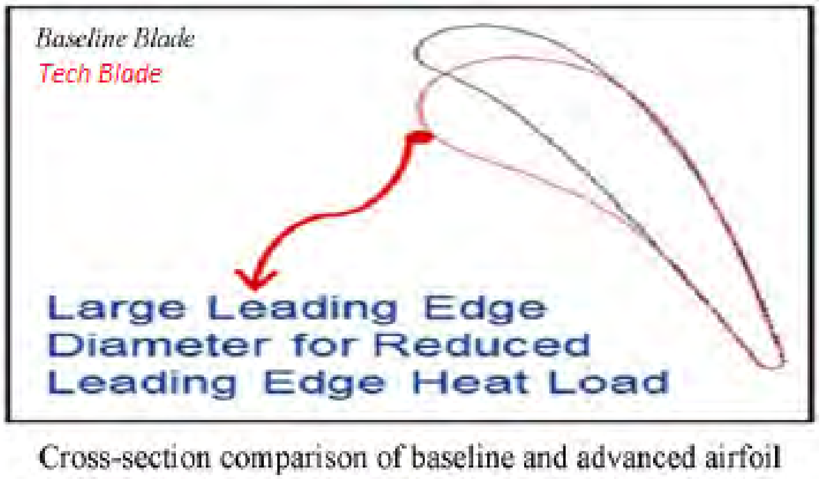

Figure 2-33. *Cross-section Comparison of the Baseline and Technology Airfoil Designs Evaluated for the CLEEN II Program, Not to Scale*

The rig assembly, test articles preparation, thermal measurement set-up and calibration was completed by 3Q 2019. The baseline airfoil tests and technology airfoil tests were then executed in 4Q 2019 and 1Q 2020 respectively. Post-processing of the acquired data including mapping of the IR thermal image data from 2D camera space to 3D part space was completed in 2Q 2020. This effort also entailed *stitching* of multiple IR camera views to generate a complete map of the airfoil P/S temperature distribution for each respective blade.

During each phase of testing, the rig inlet total pressure radial profile, total temperature radial profile, cooling flow temperature and mass flow were carefully controlled and measured to ensure consistency between test runs. The rig inlet pressure profile was measured during initial baseline airfoil efficiency tests in 3Q 2019. This pressure profile was used across all post-processing presented in this durability report. However, the rig inlet total temperature radial profile was updated during each phase of durability tests due to difference in rig temperature between durability and aero tests. The cooling air mass flow, temperature and pressure were measured in real-time during each test run.

Following completion of all tests, the test articles were sent to P&W in 4Q 2020 for post-test evaluation and data-matching. This durability post-test inspection entailed geometry inspection of the cooling features and airflow measurements and the measured data were incorporated into the overall durability cooling efficiency analysis.

2.7.2 Test Matrix

Table 2-4 shows the durability test matrix summarizing the target rig conditions. The test matrix included a total of six test conditions (herein also referred to as *test cards* A through F). These test cards represented different levels of cooling flow to the 1st Blade airfoil (TOBI Flow) and the upstream 1st Vane T/E slot. Different levels of Vane T/E slot flow were represented in test cards A, B, and C than in test cards D, E, and F. The cooling air to the 1st blade airfoil was also varied across test cards A, B, and C and similarly across test cards D, E, and F.

Table 2-4. *FAA CLEEN II Durability Test Matrix Target Rig Conditions*

Pt Inlet	Tt Inlet	Speed Parameter	Vane T/E Flow	TOBI Flow	TOBI Rail Hole Flow	
$psia$	$°R$	$\frac{N}{\sqrt{T}}$	$\%w4$	$\%w4$	$\%w4$	TEST CARD
41.3	860	367	1.90	**8.37**	1.825	A
41.3	860	367	1.90	**6.92**	1.825	B
41.3	860	367	1.90	**5.48**	1.825	C
41.3	860	367	**0.95**	8.37	1.825	D
41.3	860	367	**0.95**	6.92	1.825	E
41.3	860	367	**0.95**	5.48	1.825	F

Variation of the 1st Vane T/E flow was important in order to account for the mixing effect between the main gaspath air and vane cooling flow, which subsequently influences the temperature profile upstream of the 1st blade. In contrast, variation of the TOBI flow enabled quantification of the airfoil thermal response to cooling flow for each of the blade airfoil designs.

The target rig inlet total pressure and total temperature were measured using a single probe at midspan in real-time during IR data collection.

2.7.3 IR Data Acquisition and Mapping

A specially developed acquisition software was used to collect phase-locked thermal images of rotating blades. This software includes a number of controls including the image integration time. From a previous test campaign with similar camera hardware, the integration time was found to be a key parameter governing the signal-to-noise ratio in thermal images. Methods were developed to improve signal quality and test execution efficiency. Integration time works similarly to exposure time in photography, where long exposure time allows for good quality images, however, it does introduce blurring as the blades speed past at over 10,000 RPM. An optimization process was done to find the best integration time resulting in the highest quality image before too much blurring occurred.

The methods developed to optimize noise and integration time were largely successful; however, in any focal plane that are bad pixels that need to be accounted for. The bad pixels are caused by manufacturing defects of the sensor itself, where not every pixel responds to radiant energy in the same manner, and some pixels simply do not respond at all. The manufacturer of the IR detector claims an array operability specification of 99.5%, indicating that as many as 0.5% of all pixels in the array may not function correctly. These bad pixels will appear as a very high or very low value relative to neighboring pixels. Standard image processing methods were used to address these issues.

With the image acquisition and processing completed, the next step is the mapping process which involves transforming the thermal image data into a space where it is usable for analysis.

2.7.3.1 2D to 2D Image Mapping

To compare the experimental results with numerical predictions, both must be in the same coordinate system. The acquired infrared images are 2D, while the predictions are fully 3D. Through the use of image mapping, the 2D IR images are transformed into 3D part space. The process of converting 2D images to 3D maps is also referred to as photogrammetry and through applications in computer vision, animation, and geographic information systems (GIS), among others, the techniques to relate 2D images and 3D objects are well known and are covered in detail in various textbooks.

The goal of transforming 2D images to 3D part space is not novel; other researchers have used the technique for nose cones in hypersonic wind tunnels, airfoils for fixed-wing and rotary-wing aircraft, and blade cooling in a cascade facility. All of these studies used stationary hardware and most used a single camera view, so capturing images in a rotating environment called for some new and clever setup of instrumentation and post processing.

A computational subroutine to perform the 2D to 3D image mapping procedure was written and during development several methods were tested to find the most effective and efficient ways to perform the 2D to 3D mapping. The captured IR images were phase-locked to a particular blade view. Due to the discretization of phase to capture images, methods to identify orientation in camera space through the use of known markings (fiducial markings) are required. To describe the 3D part locations, a geometric CAD file is used as the target and image features are linked to specific 3D coordinates which can be used to create a transfer matrix which is used to transfer thermal values from the image into the 3D part space. This process is repeated for other camera views and the final mapped images stitched together on the 3D blade surface. Examples are shown in ***Figures 2-34*** and ***2-35***.

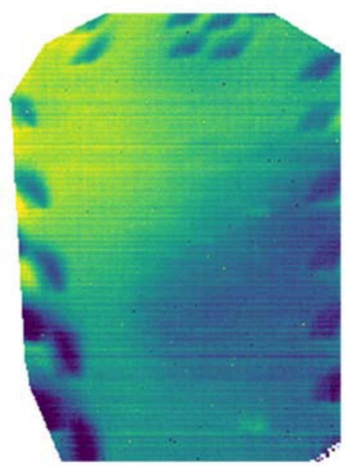

Figure 2-34. *Example 2D Thermal Image Acquired with IR system of Leading Edge and Pressure Side*

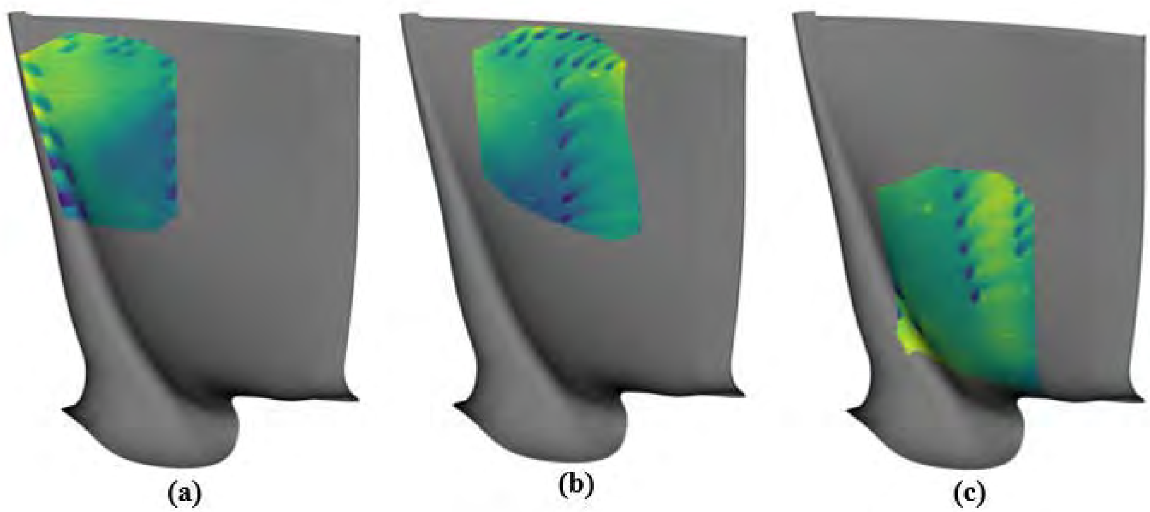

Figure 2-35. *Mapped Results for Different Blade Regions for Baseline Blade*

2.7.4 Test Data

The durability test data acquisition was carried out between Nov 2019 and January 2020, with the baseline airfoil measurements taken first. During these tests, the airfoil surface temperature was measured using an IR probe while the rig gaspath and cooling flow conditions were measured in real-time using thermocouples, pressure taps and venturi meters.

Figure 2-36 shows the measured cooling air mass flow and temperature for different test runs executed for test card A. Each of these test runs were executed on different days and confirms repeatability of the rig test conditions. Repeatability between test cards and test runs was ensured at target mass flows, main gaspath temperature and pressure conditions. The cooling air temperature fluctuated depending on the test card flow level. This variation in cooling air temperature was a potential contributor to variation in measured airfoil surface temperature between test cards and therefore had to be accounted in the data analysis.

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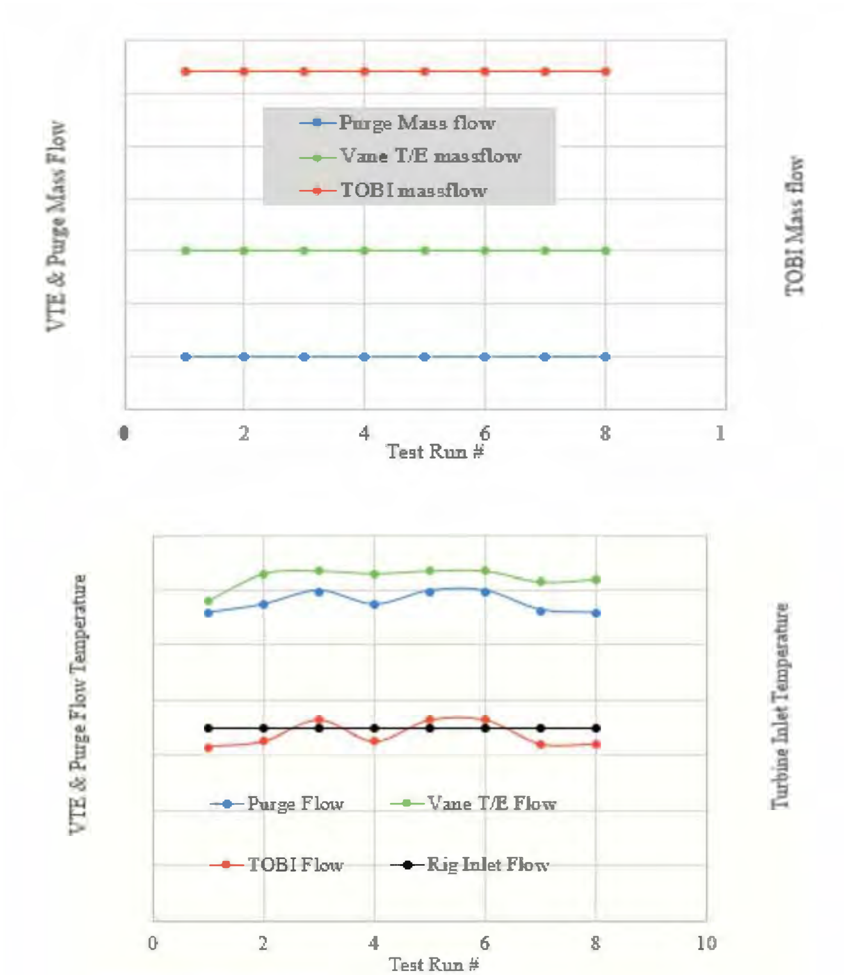

Figure 2-36. *Repeatability of Rig Test Conditions Between Runs for Tech Airfoil Test Card A*

In addition to the observed variation in cooling air temperature, the rig inlet total temperature radial profile was found to be sensitive to the level of cooling air mass flow to the vane T/E as shown in ***Figure 2-37***. The cooling flow to the vane T/E cooled the outer radius of the rig passage thereby inducing a radial temperature gradient near the outer wall of the main gaspath. This gradient in radial total temperature profile was steeper for higher vane T/E mass flow condition (test cards A, B, and C) compared to the lower vane T/E mass flow condition (test cards D, E & F). This variation in rig inlet total temperature radial profile was also a potential contributor to variation in measured airfoil surface temperature between the two sets of test cards and therefore needed to be accounted in the data analysis.

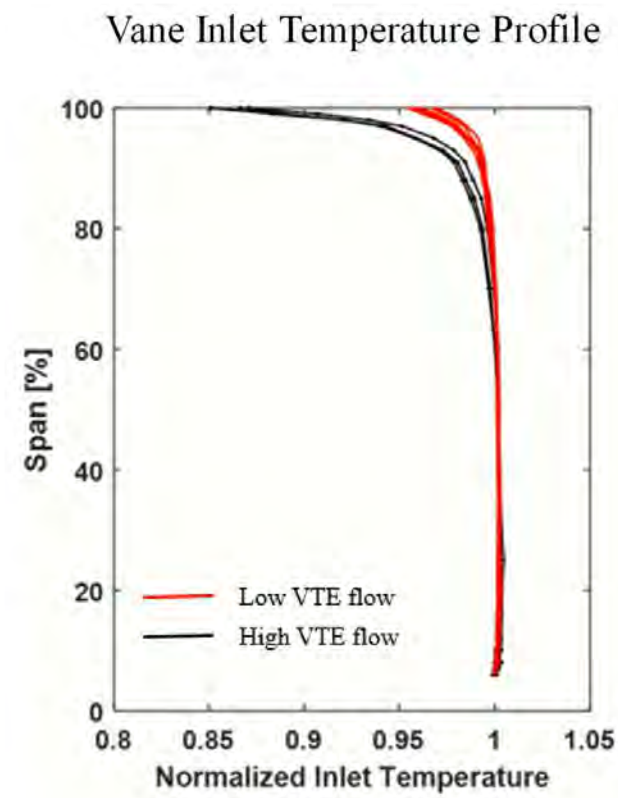

Figure 2-37. *Rig Inlet Total Temperature Radial Profile Variation With 1st Vane T/E Cooling Mass Flow*

The measured airfoil surface temperature was mapped to the 3D part model as shown in ***Figure 2-38***. Overall, the data showed decreasing airfoil surface temperature with increasing TOBI cooling flow for both baseline and tech airfoils. Furthermore, each of the airfoil designs had a unique temperature distribution footprint which was indicative of the influence of the internal core design.

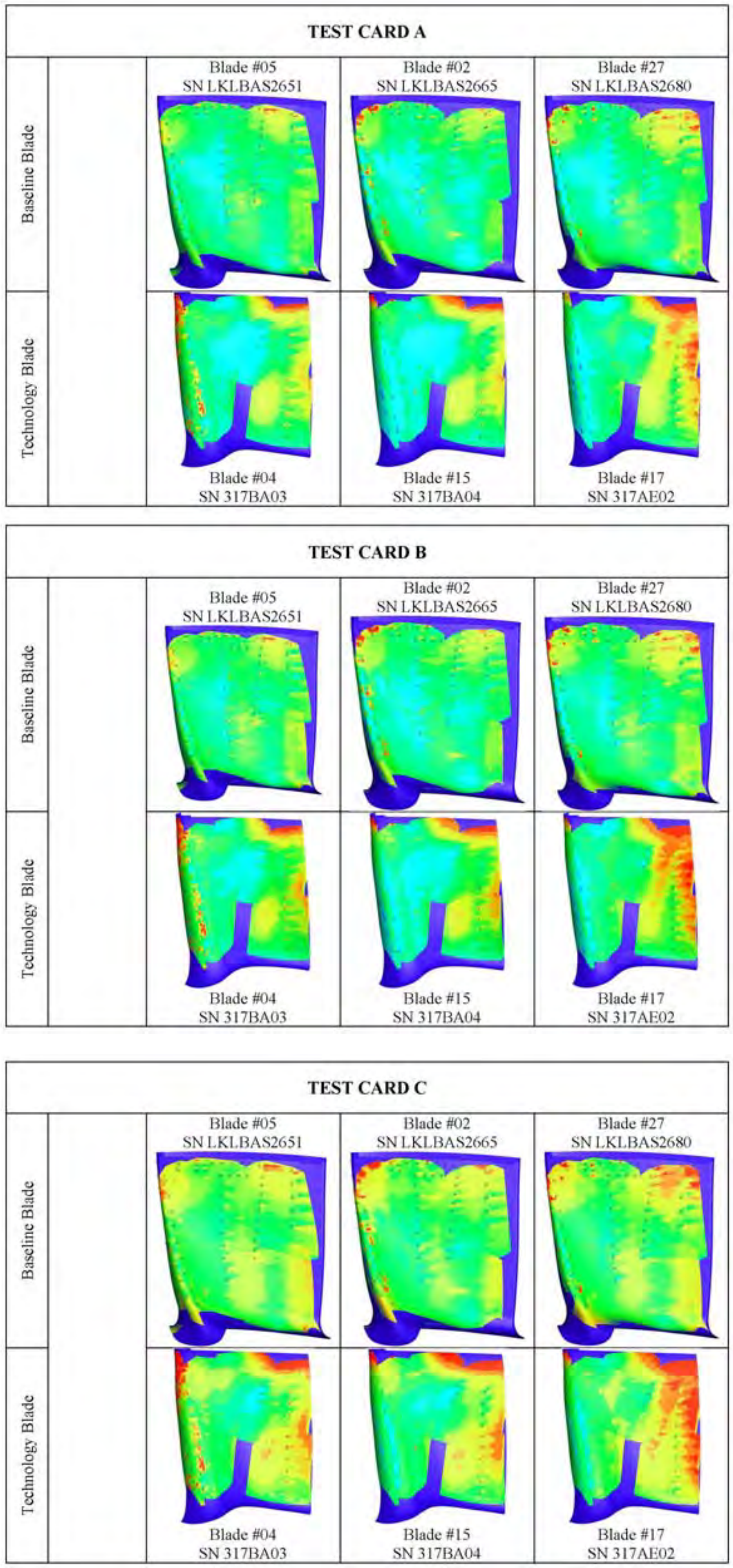

Figure 2-38. *Rig Data Summary for Baseline and CLEEN II Tech Airfoil*

There exists a significant difference in cooling hole layout on the airfoil P/S between the baseline and technology airfoil, with the latter having fewer film-cooling holes. However, despite the reduced film-cooling, the tech blade showed equivalent or lower surface temperature on the forward-P/S region of the airfoil compared to the baseline airfoil for each test card. However, the aft-P/S region, approximately downstream of the mid-chord, showed higher temperature for the tech airfoil compared to the baseline airfoil.

At this point, it should again be noted that significant modifications were applied to the tech blade T/E tip flag core passages in order to adjust overall blade flow due to manufacturing/design oversight (***Figure 4-12***). The elevated temperature in this region of the tech airfoil was in-line with the pre-test durability predictions. Because the flow circuit deviated from the design intent in these areas, the technology benefit in the T/E and tip flag regions could not be quantified with meaningful accuracy in these regions from these test results.

2.7.5 Post Test Inspection

Following completion of all the rig tests in 4Q 2020, the blades were sent to P&W facility for inspection. This was necessary in order to obtain geometric and airflow characteristics for each of the airfoils. The post-test inspection process included visual inspection of the part coating, external geometry, film-cooling holes and bench top airflow. Each core on the part was air flowed independently to determine its flow characteristic and the measured flow data was used to data match the durability model. The total blade airflow data showed that the tech airfoils were under-flowing on average relative to its design intent. In contrast, the detailed individual core airflow data indicated the pressure side skin cores in some parts were under-flowing while in others were over-flowing relative to design intent.

2.7.6 Overall Cooling Efficiency Analysis

In order to quantify the overall cooling efficiency benefit for the tech airfoil relative to the baseline airfoil, consideration had to be given to the aforementioned variations in rig boundary conditions which could potentially influence the measured airfoil temperature. This includes differences in geometry between airfoils which affect cooling flow delivery and rig operating conditions difference between test cards. Therefore, a direct comparison of the airfoil surface temperature differences does not suffice in drawing conclusions on the overall technology cooling benefit.

In the first part of this effort, the impact of variation of the rig inlet total temperature radial profile due to vane T/E flow was accounted by leveraging CFD. A full stage CFD model of the test rig was executed to determine the interstage temperature profile upstream of the 1st blade as shown in ***Figure 2-39***. This interstage temperature profile was then non-dimensionalized into a profile factor which is a function of the vane T/E flow temperature and rig inlet temperature as shown in the equation below. This allowed for the blade inlet profile i.e downstream of 1V, to account for the 1V T/E flow temperature and the rig inlet profile for each test card/test run.

$$Profile\ Factor = \frac{T_{gas} - T_{t4.1,Avg}}{T_{t4.0} - T_{1V\ TE}}$$

where

$$T_{gas} = Local\ average\ gas\ temperature$$

$$T_{t4.1,Avg} = Station\ 4.1\ average\ gas\ temperature$$

$$T_{t4.0} = Station\ 4.0\ average\ gas\ temperature$$

$$T_{1V\ TE} = Upstream\ 1V\ trailing\ edge\ slot\ flow\ temperature$$

In order to account for core manufacturing deviations and resulting flow deviations, the flow splits through each airflow core at rig conditions was determined for each test card. The flow model used to generate these cooling air flow splits had been data-matched using the post-test airflow data for each airfoil. In addition to that, the external airfoil surface was discretized into regions based on internal core design directly influence the surface temperature of that region. This allowed for the measured surface temperature to be directly correlated to the amount of cooling air delivered to that region of the airfoil.

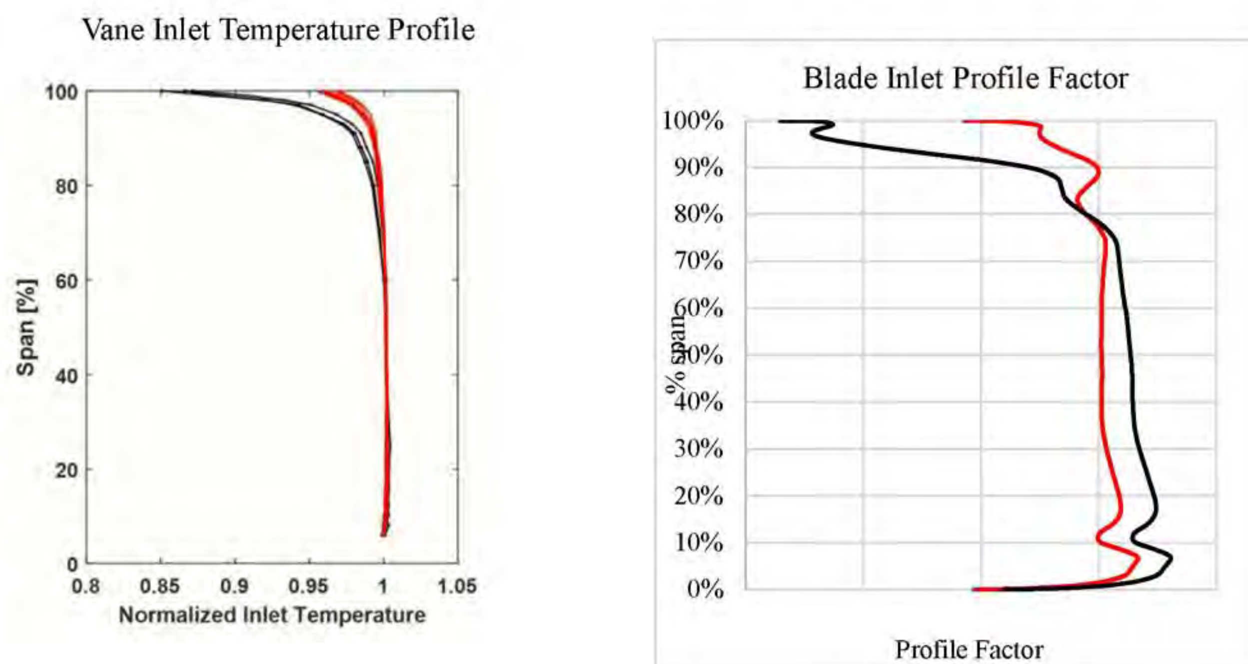

Figure 2-39. *Effect of START Rig Inlet Radial Temperature Profile on Interstage Temperature Profile Factor Upstream of 1st Blade as Predicted Using CFD*

Finally, the airfoil surface temperature was nondimensionalized into cooling effectiveness (Phi Φ) which accounted for cooling air temperature and blade upstream temperature. The cooling effectiveness (Phi Φ) was then correlated to the core flow heat load parameter (Beta β) to generate a cooling technology curve for each airfoil surface region. The cooling technology efficiency was assessed for only the P/S skincore regions of the tech airfoil relative to the forward P/S region of the baseline airfoil.

Figure 2-40 shows the generated cooling technology curve derived from the measured airfoil surface temperature. The technology curve confirms increased overall cooling effectiveness on the airfoil P/S of the tech airfoil compared to the baseline airfoil. This confirms that the tech airfoil requires less cooling flow to achieve a target blade temperature compared to the baseline airfoil, hence the CLEEN II tech cooling benefit.

$$Phi,\ \emptyset = \frac{T_{41} - T_{surf}}{T_{41} - T_{cool}}$$

$$Heat\ Load\ Parameter = \frac{W * C_{p_{coolingAir}}}{H_{gas} * A_{surf}}$$

where:

$$\boldsymbol{T_{41}} : Blade\ inlet\ Temperature$$

$$\boldsymbol{T_{surf}} : Blade\ surface\ Temperature$$

$$\boldsymbol{T_{cool}} : Core\ Supply\ Temperature$$

$$\boldsymbol{W} : core\ mass\ flow$$

$$\boldsymbol{C_{p_{coolingAir}}} : Cooling\ Air\ Heat\ Coefficient$$

$$\boldsymbol{A_{surf}} : External\ Surface\ Area$$

$$\boldsymbol{H_{gas}} : External\ Surface\ Heat\ Transfer\ Coefficient$$

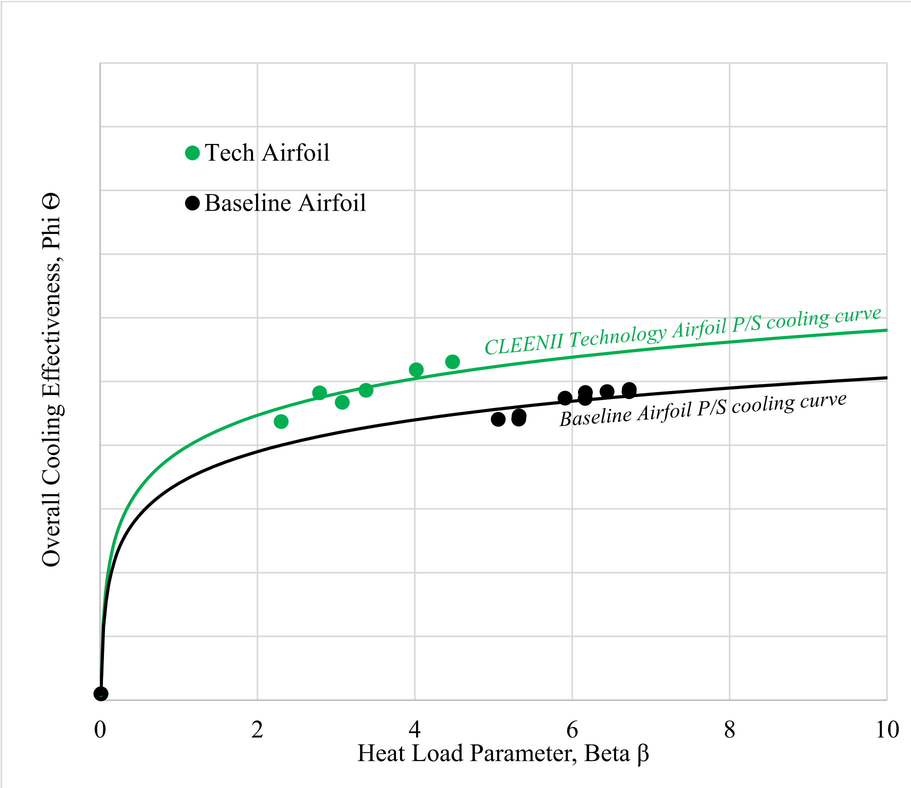

Figure 2-40. *Cooling Technology Curve for the Baseline and Tech Airfoil P/S*

Figure 2-41 shows the projected CLEEN II airfoil P/S cooling efficiency benefit derived from the technology curves. At any given Phi Φ, the difference in Beta β between the two technology curves can be used to estimate cooling credit to the airfoil P/S resulting from CLEENII technologies. The tech airfoil showed a cooling efficiency benefit of 27.5% relative to the baseline airfoil based on the measured data.

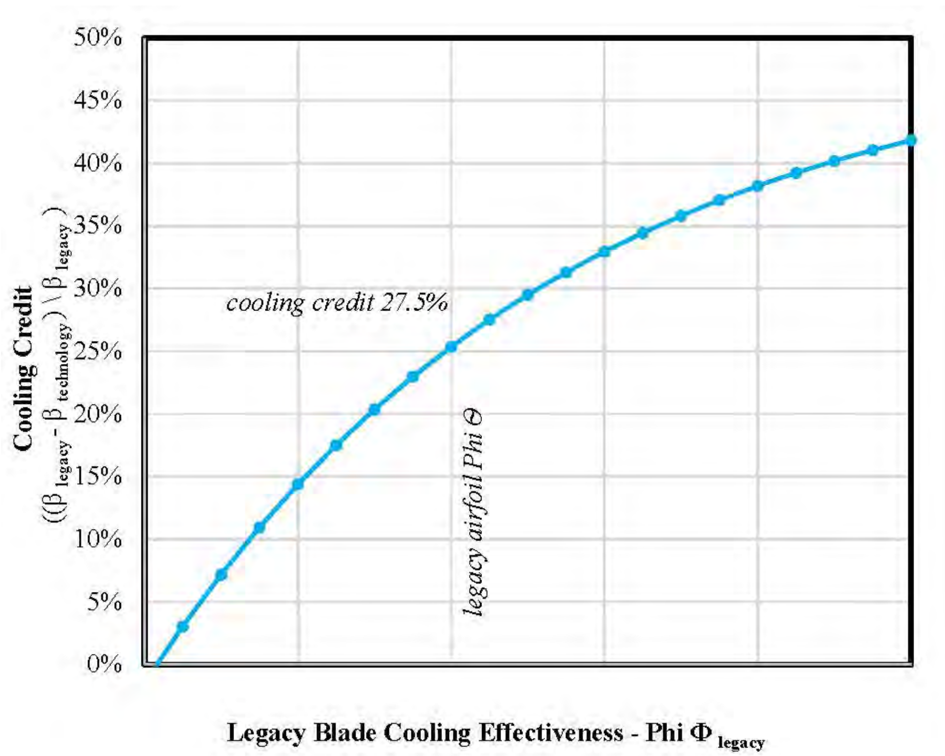

Figure 2-41. *CLEEN II Airfoil P/S Technology Cooling Credit Curve Relative to Baseline Airfoil*

2.7.7 Durability Summary, Conclusions, and Future Opportunities

The FAA CLEEN II program set out to demonstrate advanced cooling technologies packaging and application on a turbine airfoil and associated cooling efficiency benefit. To this end, the P&W durability team leveraged both passive and active advanced cooling concepts on a 1st blade design. Passive cooling was incorporated through an inter-disciplinary collaboration between turbine aero and durability to design an optimized external airfoil geometry to reduce and redistribute external heat load. The airfoil was also designed to allow packaging of advanced convective cooling technologies internally.

This advanced double wall airfoil was used to benchmark, learn and advance manufacturing process at P&W for future commercial products. The airfoil used in this CLEEN II testing contained manufacturing non-conformances which were accounted for in the overall program objective to quantify the cooling benefit. The negative learning at the time of test article production was since carried forward to positively impact current manufacturing process at P&W which is an enabler for use of advanced cooling concepts for durability.

Advanced infrared thermal imaging architecture and data processing algorithm was developed to enable measurement of blade P/S temperature in a rotating turbine environment. Additive manufacturing was leveraged to support the thermal imaging architecture in the turbine within precision accuracy of ~+/-2.5°F. Temperature measurements taken on the CLEEN II technology airfoil were compared to those from the baseline P&W airfoil and indicated a P/S cooling efficiency benefit up to 27.5%.

The success from the current program has provided insight for potential opportunities for future work in advance turbine cooling technology. Specifically, a similar study on the blade S/S and tip regions which are critical to turbine performance is recommended. Furthermore, airfoil heat flux measurement is recommended in order to quantify heat load redistribution.

2.8 CONCLUSION

The FAA CLEEN II cooled-rig test campaign represents the first cooled turbine test in this new experimental facility, as well as the first cooled HPT first-stage test run by P&W with modern designs. While the benefits of this collaboration are many, with details presented in the body of this report, the main findings are as follows:

1. Following application of bookkeeping steps to account for hardware non-conformances and boundary condition issues, the tech blade design was shown to provide a performance benefit of 0.1% compared to the baseline design. The results are very close to the predictions and considering the experimental and predictive uncertainties the test is a success for P&W.
2. Substantial learning was garnered regarding multi-stream efficiency measurements in a complex, cooled HPT first stage, such as the importance of accurately controlling and measuring the boundary conditions of each fluid stream which affects the efficiency calculation.
3. The importance of detailed hardware inspection data to support accurate performance bookkeeping between test configurations and for translation of the results to product applications.
4. The importance of test data quality criteria and risk-reduction testing standards to avoid the need for re-testing and for maximizing data accuracy and repeatability.
5. Finally, this work allowed extensive learning and process development for the execution of cooled-turbine performance and durability testing, without the undue schedule pressures tied to engine program funding.

In addition to the achievements of the aero-efficiency tests and the learning gained from this program, the durability assessment was also very successful. The specific durability goals of the CLEEN II program were achieved in testing out new double-wall cooling architectures and advancing manufacturing readiness. The anticipated reduction in cooling flow required was also achieved and increased cooling efficiency of 27.5% was demonstrated.

Along with these successes in the CLEEN II objectives, the rig was upgraded to allow for state-of-the-art image gathering capabilities, and the temperature data gathering that this equipment allows will continue to advance the understanding of turbine blade cooling properties well into the future. There are already several more tests planned for the START rig which continue where CLEEN II left off and offer even greater understanding and advancements in blade technology.

3. HIGH-PRESSURE COMPRESSOR CORE TECHNOLOGIES TESTING

3.1 INTRODUCTION

Development of the Next Generation Product Family (NGPF) HPC began circa 2005. The HPC has been used on the highly successful GTF products developed at Pratt & Whitney. As the product has matured, and compressor development learning has been acquired, opportunities for technology insertion to further improve the compressor performance have been desired.

The CLEEN II program supported the testing of a full compressor rig design that incorporated several advanced technologies. The data acquired has successfully provided insight to the effects of various technologies applied to the compressor. Overall, the test data has showed a better than expected efficiency improvements across the full power range as well as improved high power stability.

3.2 HPC CORE TEST OBJECTIVES

The primary test objectives for the CLEEN II program are to:

- Mature and de-risk advanced GTF HPC technologies
- Fully characterize the advanced GTF HPC

The technologies included in the CLEEN II compressor design include:

- Reaction Reduction
- Solidity Reduction
- Leakage Reduction
- Surface Finish Improvements
- Aero-Structural Optimization Improvements

To fully characterize the advanced technology HPC, the following effects were tested with the fully intra-stage instrumented compressor:

- Inlet Profile Effects (Axisymetric)
- Distortion Sensitivity (Non-axisymetric)
- Bleed Modification Sensitivities
- Vane Optimization and Sensitivities
- Reynolds Number Sensitivity
- Transient Operation Effects

3.3 HPC TEST SETUP

3.3.1 Rig Configuration Overview

The HPC technology rig was developed as a joint program with MTU Aero Engines AG of Munich, Germany. The HPC Rig configuration included the following features:

- Eight Compressor Stages
- Intermediate Case Struts
- Variable Vanes
- Bleeds

- Diffuser Strut

Test capabilities included:

- Ability to add, change, or remove inlet screen
- Traverse Probes at HPC inlet to capture circumferential variation across passage
- Traverse Probes at HPC exit to capture circumferential variation across passage
- Turbulence probes at inlet

3.3.2 Instrumentation

The HPC was fully instrumented in order to gain as much knowledge as possible about the internal and overall functionality of the HPC. The instrumentation included:

- Case temperatures and pressures
- Static pressure kulites
- Strain Gages
- Clearance Measurements
- Accelerometers
- Resolvers
- Kielheads for internal total pressure & total temperature measurements

The HPC inlet was characterized using a traverse probe. Multiple locations for the total pressure (Pt) and total temperature (Tt) sensors were used to provide additional confidence in efficiency calculations. Wall static instrumentation on the Intermediate Case (IMC) verifies that the HPC matches engine boundary conditions.

Every vane stage in the HPC includes kielheads in order to understand the detailed stage matching. The resolvers provide the feedback that variable vanes are operating in the commanded angles. The kulites are used to determine when and where the compressor instability initiated. The kielhead pressures and temperatures allow a stage-by-stage mapping of the compressor to understand the stage matching as well as detailed radial profiled information. The clearances for each rotor were measured throughout the test. Rotor stresses could also be observed through the non-contacting timing system.

Multiple circumferential locations at the exit plane measurement of total pressure and total temperature allowed for higher confidence in efficiency calculations. The exit pressure traverse was used to understand the circumferential variation, including detailed wake information..

3.4 TEST PROGRAM

The Major Test Program Elements of the HPC Technology test were the following:

- Optimize Stator Vane Schedule (SVS)
- Define performance (efficiency/stability) across full operating envelope
- Define performance and surge line sensitivity to:
  - Vane Angle
  - Rotor tip clearance
  - Inlet profile
  - Inlet distortion

— Bleed variation

— Reynolds Number

The test started with running speedline characteristics across from idle to design speed to obtain efficiency/stability information at very tight clearances. The *break-in* and *rub-in* procedures were performed in order to *nibble* or take small increments of rub in order to safely set the clearances to the desired level. The break-in was accompanied by post-run compressor borescope inspections to verify clearance levels.

A Design of Experiments (DOE) was run at multiple speeds in order to optimize the vane setting to balance efficiency and stability margin capability. Once the optimum vane settings were determined for idle through overspeed conditions, the HPC was mapped out at the various conditions to obtain efficiency lapse rates and stability margin.

Inlet profile studies were then performed. In an engine environment, the operation of the Low Pressure Compressor (LPC) affects the profile entering into the HPC. The HPC must be able to maintain stability margin for various profile entering the HPC, and therefore it is important to understand the implications of an altered inlet profile. Non-circumferential uniform distortion can also enter the HPC and therefore a 180-degree distortion test was run.

Sensitivities of individual, variable vane angles, the impact of stage proportionality, and bleed variation were all captured across the full compressor operating map. Throughout the development of an engine, it is necessary to adjust variable vane angles bleed levels, thus it is imperative to understand these sensitivities and impacts.

Reynolds number variation was also tested in the rig campaign. As the altitude of the engine varies from sea level up to the mission altitude, the Reynolds number varies substantially. This tends to alter efficiency and stability margins. Tests of Reynolds Number impact allows for full operational envelope understanding.

3.5 BASELINE RESULTS

3.5.1 Performance

3.5.1.1 Efficiency

The efficiency benefit of the CLEEN II research is based on providing benefits from not just improved aerodynamics, but knowledge of the boundary conditions, and improved mechanical design features that support improved aerodynamics.

The aerodynamics modified to provide a benefit include:

- Reduced reaction
- Reduced solidity
- Airfoil Optimization
- Endwall Optimization

The benefits from the mechanical design features include:

- Reduced leakages
- Improved surface finish
- Improved rub system
- Aero-structures optimization improvements

The non-*aerodynamics* benefits account for about half of the efficiency benefit of the compressor, which confirms the statement of "the devil is in the details."

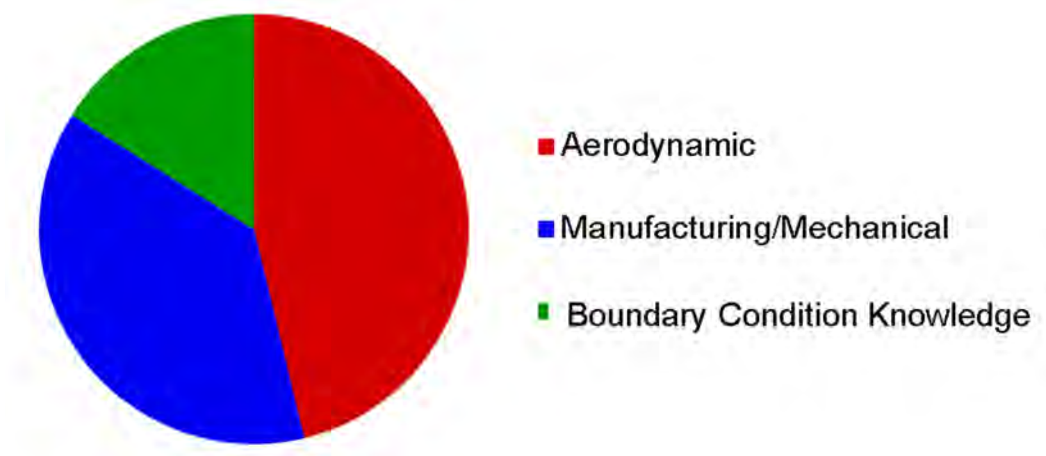

Figure 3-1. *Source of Performance Benefits*

The measured efficiency from the rig needed to be adjusted to account for rig specific boundary conditions in order to project the performance to an engine. As explained earlier, the rig is heavily instrumented in order to gain insight into the internal details of the compressor, but this does incur a loss due to the extra surface area/friction from the instrumentation. The clearances are then adjusted for expected product relevance. Since the test is primariily run with ambient inlet conditions, the effect of the boundary condition needs to be adjusted to a flight condition with an LPC in front of the HPC. Other small concessions such as hardware concessions and inlet profile differences account f or small adjustments as well. ***Figure 3-2*** shows that the instrumentation loss is the largest adjustment made to the measured performance to project to product expectations.

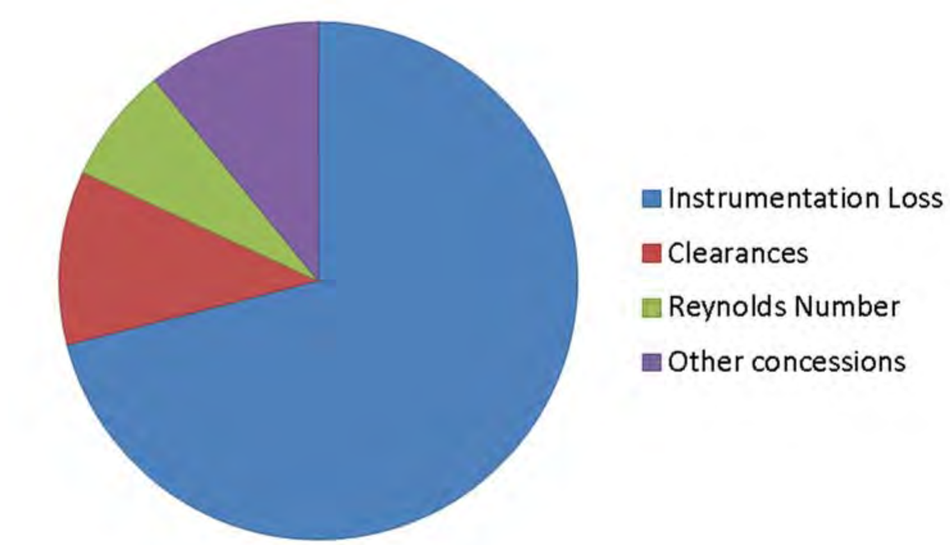

Figure 3-2. *Efficiency Bookkeeping to Measured Expectations*

3.5.1.2 Inter-stage Learning

The stator leading edge kielhead data provide valuable pressure and temperature understanding. ***Figure 3-3*** shows a comparison of the data in green versus the pre-test expectation from CFD in red. The kielhead pressure and temperature sensors provide radial distributions across every stage on stator leading edges. The radial profile data provides insight to if the weakness of the compressor is generated in the inner diameter or the outer diameters of the airfoils. The inter-stage pressure and temperature data can also be used to look at individual quasi (stator leading edge-to-stator leading edge) stage compressor maps of pressure ratio versus corrected flow. ***Figure 3-3*** shows that at high power, CFD had relatively good predictive capability to the stage matching.

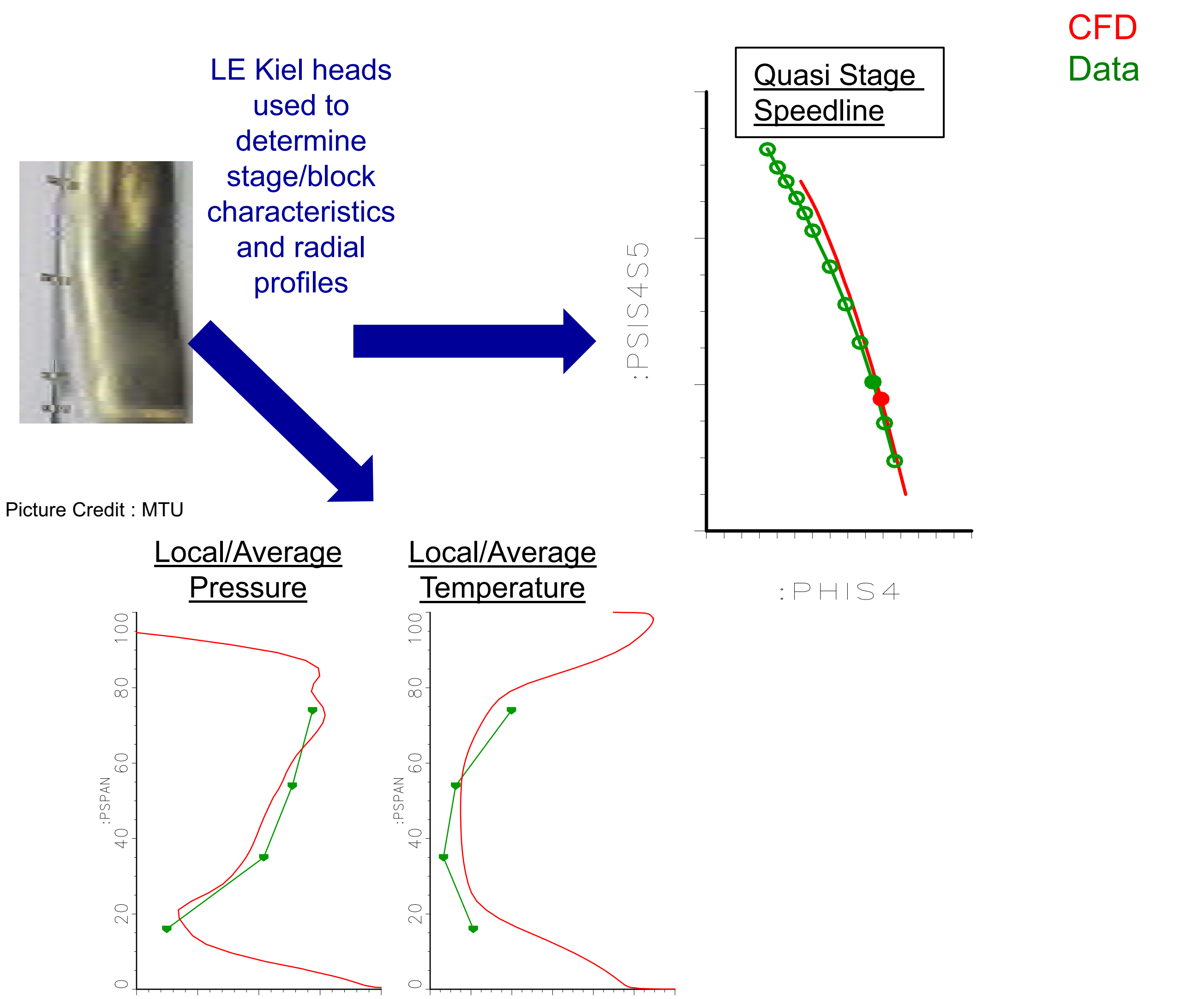

Figure 3-3. *Data Versus CFD Comparison of Inter-stage Pressures*

Figure 3-4 shows the results of a Stator Surface Static Measurement (green) that is transformed into an airfoil mach distribution and compared against CFD (red). At high power, the mach distribution is very well-aligned with expectation. The surface static pressure measurement can be used to determine if the stator leading edge incidences are not aligned with expectations. It can also be used to determine if a stator separates prior to expectation.

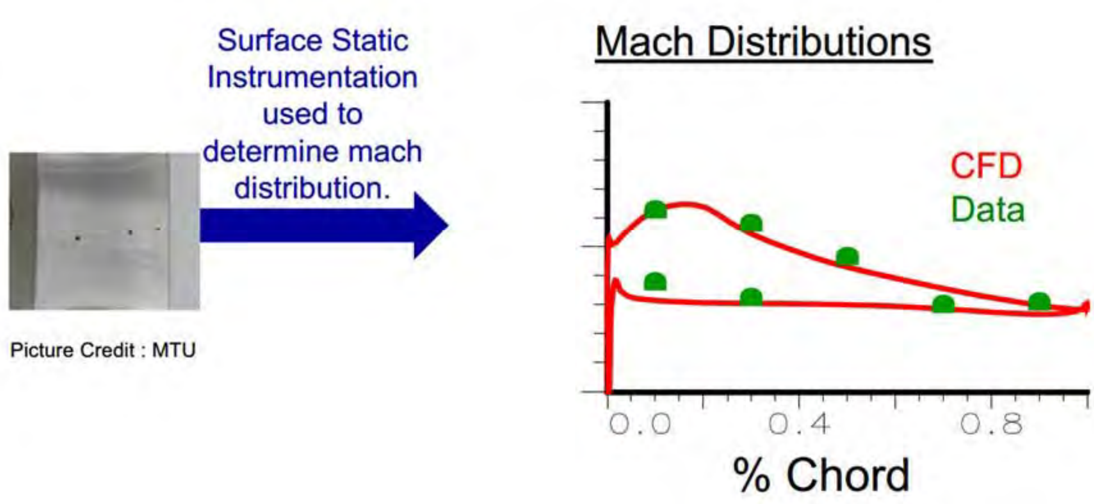

Figure 3-4. *Stator Surface Static Measurement Versus Prediction*

3.5.2 Vane Optimization

Vane optimization was performed to balance the efficiency and stability requirements at various speeds including starting, idle and cruise. The variable vanes are then proportionally tied to the IGV to form curves to meet the needs of the various operating conditions.

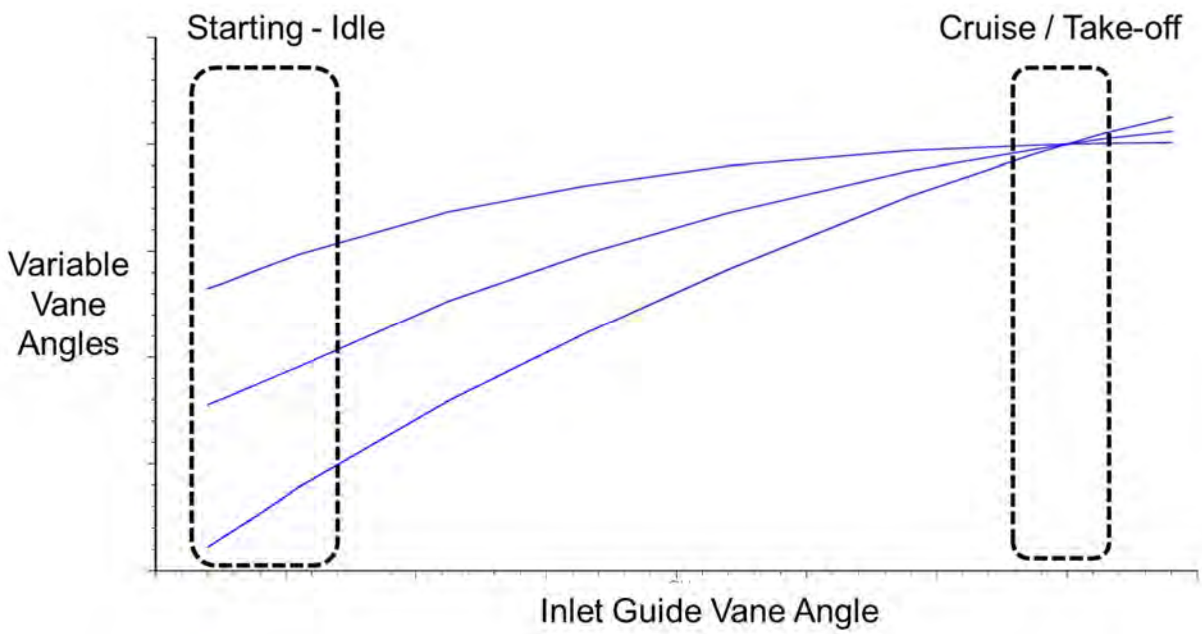

Figure 3-5. *Outcome of Vane Schedule Optimization*

3.6 SENSITIVITY TESTING

3.6.1 Inlet Profile

As mentioned previously, inlet profile studies were then performed. The operation of the LPC affects the profile entering into the HPC. The HPC must be able to maintain stability margin for either profile entering the HPC, and therefore it is important to understand the implications of an altered inlet profile. Non circumferentially uniform distortion can also enter the HPC and therefore a 180 degree distortion test was run.

The inlet profile of the compressor is altered by modifying a screen inserted at the inlet of the rig. The screen is made up of a wire mesh. The mesh creates a radially varying pressure loss. ***Figure 3-6*** shows the radial variation in the inlet profile at high power resulting from the various inlet screen designs.

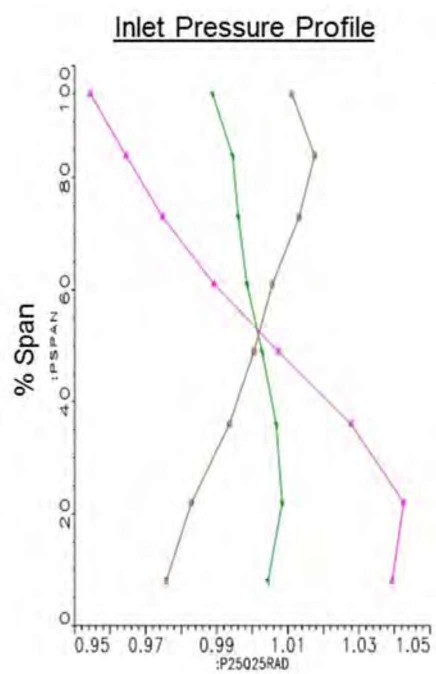

Figure 3-6. *Measured Inlet Profile Variation at Design Speed*

3.7 CONCLUSIONS

In conclusion, the testing performed in 2016 on the HPC technology rig was extensive and allowed for comprehensive learning on the new compressor developed at P&W.

The compressor was fully instrumented in order to understand the internal details of the compressor. Sensitivity testing of vanes, clearances, inlet profiles, bleeds and Reynolds Numbers allowed for further understanding of the benefits and limitations of the new compressor.

The advanced technologies validated under the HPC core testing work has since been incorporated into P&W's product offerings and sets the baseline for all future P&W products.

4. SINGLE-ELEMENT CASCADE TEST INFORMATION

4.1 OBJECTIVES

The SEC test study was designed to bridge the gaps between durability and aerodynamic disciplines, as well as fundamental flat-plate experiments and expensive rig/engine tests. To this end, film cooling effectiveness and aerodynamic losses are measured for a current state-of-the-art airfoil design. Such detailed measurements are necessary to enhance the understanding of the physical mechanisms that govern the intricate interactions between the film cooling jet and the local boundary layer. Measurements are compared between standard and advanced cooling hole shapes at engine-representative operating conditions in order to investigate the effect of cooling hole geometry on performance and durability metrics. The advanced cooling hole shape was developed by executing a hole geometry optimization aimed at maximizing the film effectiveness downstream of the cooling hole on a flat plate. It was subsequently tested in a PSU low-speed, flat plate test facility which confirmed an improved cooling effectiveness at low Mach number conditions.

Furthermore, the generated test data represents valuable, benchmark-quality aero/thermal data, which can be used to improve the predictive capability of next-generation film-cooling modeling using computational fluid dynamics (CFD) solvers.

4.2 TEST PLANNING AND EXECUTION

Before the start of the FAA CLEEN II contract, P&W had initiated the conceptual design studies for SEC testing and determined that the RTRC as the most suitable facility to execute the testing. The SEC provide a number of advantages; namely, comparatively low flow requirements, relevant engine conditions, highly resolved measurements supported by a scaled design and modular rig design which allows for easy testing of multiple airfoil shapes and cooling configurations.

In 2013, P&W completed Phase I of design and construction of the SEC and demonstrated its capability. In the last quarter of 2016, RTRC began to design and build the required modifications specific for the FAA CLEEN II test airfoils target rig conditions. The facility modifications and test article assembly were completed in March 2018. Upon completion of the assembly of the facility and test article, which included several rounds of internal design reviews, the CLEEN II SEC tests were carried out between April 2018 and June 2018. Additional tests were also conducted in November 2018 under P&W IR&D funding to enhance understanding of the preliminary testing results. The final test results were presented to the FAA audience in March 2019 and the final test report in June 2019. The SEC test schedule is outlined in ***Figure 4-1***.

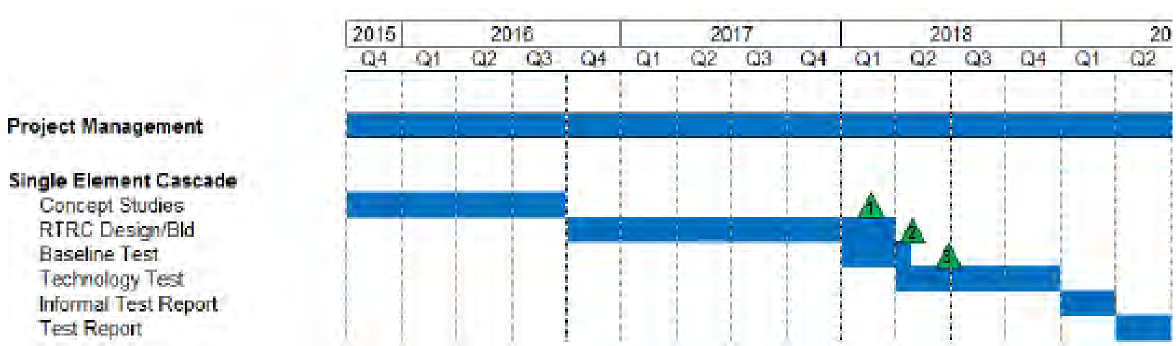

Figure 4-1. *FAA CLEEN II SEC Testing Schedule*

4.3 TEST SET-UP

4.3.1 Cascade Configuration Overview

The basic function of the Single Element Cascade is as follows. Compressor air enters the cascade through a venturi which measures the mainstream mass flow through the cascade. The air is then heated using electrical heaters, after which it enters a larger chamber with a screen for flow conditioning. The flow then passes through a turbulence grid located at the test section inlet which results in approximately 5% freestream turbulence intensity. The air finally goes through the cascade test section where the test airfoil is located before exiting through an ejector system controlled by a series of valves.

IR thermography is used to measure airfoil surface temperature of the cooled airfoils. Measurements of the airfoil surface temperature as well as plenum and the cascade inlet total air temperatures are used to calculate the adiabatic film-cooling effectiveness at a given cooling flow rate. The adiabatic film-cooling effectiveness is defined as:

$$\eta = \frac{T_r - T_w}{T_r - T_c}$$

Equation 1

where T_r is the local recovery temperature, T_w is the measured wall temperature and T_c is the temperature of the cooling air. The airfoil was also spray painted with a thin layer of flat-black paint of known emissivity.

A total of five anti-reflective coated windows were installed along the guidewalls and the endwall and of the test section for IR optical access. The IR windows were positioned such that the entire airfoil surface temperature could be captured using the infrared cameras.

4.4 TEST ARTICLES AND TEST MATRIX

The airfoils tested in the SEC are two-dimensional, prismatic airfoils extracted from a section of a three-dimensional advanced low heat-load airfoil which is also being tested in the FAA CLEEN II PSU START rig. First, a cross-section of the three-dimensional engine airfoil was extracted. The two-dimensional airfoil shape was then scaled up and extruded to cover the span of the cascade. The larger scale allows for better feature resolution of the additively fabricated airfoil and cooling hole shapes while enabling highly resolved surface IR measurements.

To investigate the aero-thermal performance of advanced film-cooling on the SEC airfoil, three rows of film-cooling were strategically placed around the airfoil. The cooling flow to each row was controlled independently since each row is supplied with cooling air via individual plenum. ***Figure 4-2*** shows a cross-section of the test airfoil as well as the location of the pressure-side row — PB, suction-side row — SA, and leading-edge row — SH. Cooling on the leading edge of an airfoil is often also referred to as showerhead cooling.

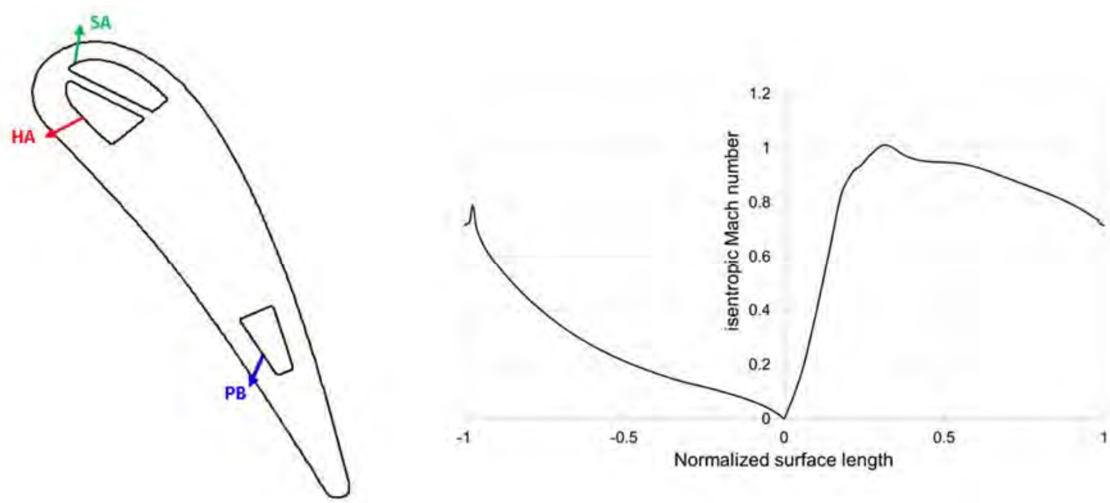

Figure 4-2. *SEC Airfoil Cross Section (left) and Pressure Distribution (right)*
For both images, the location of the cooling rows is also shown.

Two test airfoils, A1 and A2, were fabricated with standard and advanced cooling hole geometries, respectively. To facilitate implementation of internal instrumentation for measuring the plenum total pressure and temperature, each airfoil was assembled from three additively fabricated pieces i.e., the hub, midspan and tip section of the airfoil were additively fabricated separately. The parts at hub and tip were similar between airfoil A1 and A2 airfoil, while the midspan section of the airfoil is unique for A1 and A2 due to different cooling hole shapes. ***Table 4-1*** provides a summary overview of the cooling hole shapes used for each cooling hole row on each test airfoil.

Table 4-1. *Cooling Hole Shapes for SEC Airfoils A1 and A2*

	HA	***PB***	***SA***
A1	Round	Shaped	Shaped
A2	Shaped	Advanced	Advanced

For film cooling testing using airfoils A1 and A2, a total of three blowing ratios were considered: low, medium, high, where the choice of blowing ratios was guided by corresponding real engine applications as well as the PSU rig test. The blowing ratio is defined as the mass flux ratio between the coolant flow and the mainstream gas flow locally at the injection of cooling.

$$BR = \frac{(\rho V)_c}{(\rho V)_g}$$

Equation 2

Note that the cooling hole footprint for the advanced cooling holes is larger than that of the standard shaped hole geometry. In order to maintain the same mechanical coverage (an indicator of the lateral average film-effectiveness of a film-cooled surface) the spanwise hole distance for the advance hole row was increased in order to maintain the same mechanical coverage between airfoils A1 and A2.

4.5 RIG AND TEST ARTICLE MANUFACTURING

The aforementioned rig components as well as test article airfoils were all new and prerequisite equipment requiring design, manufacturing, and integration and/or testing to ensure the SEC rig would function as intended.

Conceptual design work had begun in late 2016, with the manufacturing stage beginning in late 2017. A review of P&W's previous SEC work was conducted prior to beginning design work to allow knowledge gained to be leveraged for the FAA CLEEN II testing. This resulted in improved sealing between the cooling air manifolds and plenums to prevent cross-talk and leakage, maximized uniformity of blowing ration across span, elimination of blind spots due to changed IR window location/sizes, improved IR camera fidelity due to improved multi-point calibration, and improved steady state due to improved flow conditioning grid designs.

As previously mentioned, a total of five anti-reflective coated windows were installed along the guidewalls and the endwall of the test section for IR optical access. The IR windows were positioned such that the entire airfoil surface temperature could be captured using the infrared cameras. The design and manufacturing of these windows benefited from the previous experience from SEC rig and the subsequent design studies conducted thereof. The figure below shows one of the rectangular window sections prior to installation into the SEC rig.

A variety of new technologies and features were assessed for inclusion in the airfoil design. Details of this process and selection, as well as discussion of the design elements themselves, were outlined in section 2.4. This process concluded in mid-2017 and an assessment on appropriate additive manufacturing processes was made prior to work beginning on manufacturing the SEC airfoil test articles. The requirements for the additively manufactured airfoil sections included low conductivity for accurate film effectiveness measurements, ability to be hermetic, and accurate and repeatable geometry creation. A review of available data and experience led to a downselect of the appropriate process and material. A variety of benchtop tests and inspections then followed to prove out the suitability of the process and material. The tests included leak tests to confirm non-permeability, white light interferometry of a preliminary featured airfoil design to gauge print quality, and benchtop thermal conductivity measurements.

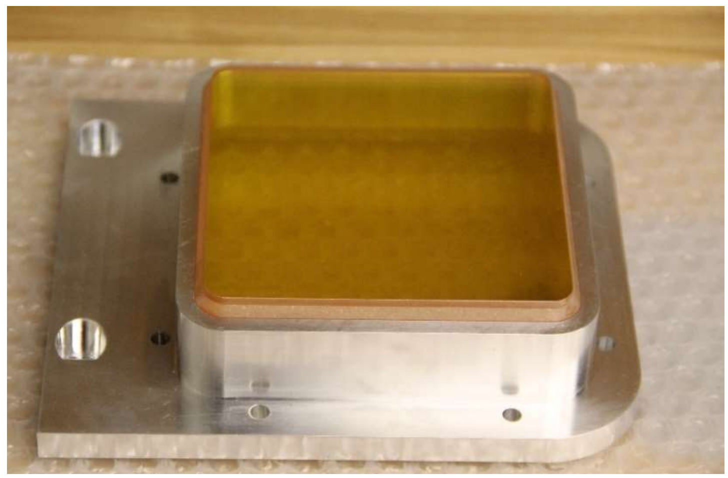

Figure 4-3. *Rectangular Flat Window Manufacturing Component*

With the material/process selection and detailed design process now finished, the actual manufacturing of the airfoils began in the second half of 2017. The manufacturing process included not only the 3D printing of airfoils, but also the instrumentation, calibration, flow visualization and other prerequisite tests needed to ensure repeatable and quality data during the test campaign. ***Figure 4-4*** shows one of the uncooled airfoils used for flow visualization and calibration.

Figure 4-4. *Flow Visualization and Calibration Airfoil*

Following all cooled and uncooled tests, visualizations and calibrations, the rig was assembled and prepped for the testing campaigns to begin in early 2018. The assembled and instrumented rig is shown below as well as outline of the SEC schedule. The tests were concluded with the results available prior to full span START Rig rotational testing later on in the program.

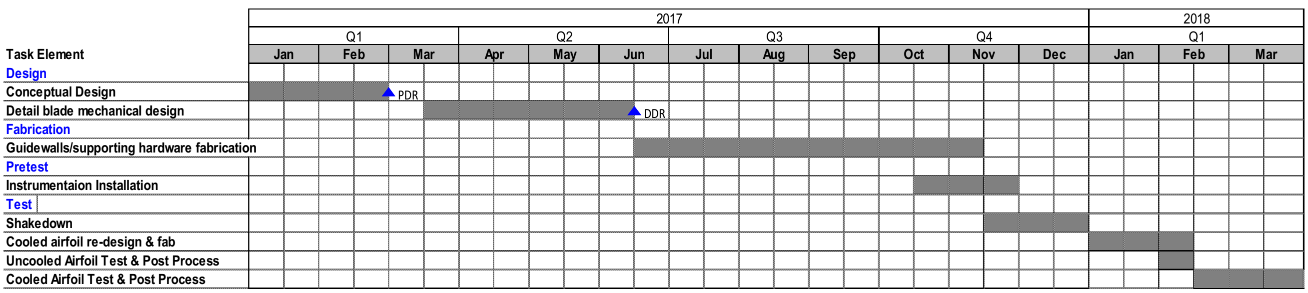

Figure 4-5. *Overview of SEC Design, Manufacturing, and Test Schedule*

4.6 TEST RESULTS

Several uncooled airfoils were tested at the beginning of the experiments in order to verify the intended rig condition and instrumentation functionality. During that process, static pressure taps were placed at midspan around the airfoil surface and cascade guidewalls to establish the intended airfoil loading and Mach Number distribution. The measurements were compared to CFD prediction as shown in ***Figure 4-6***, and a good agreement was observed relative to the design intent (CFD).

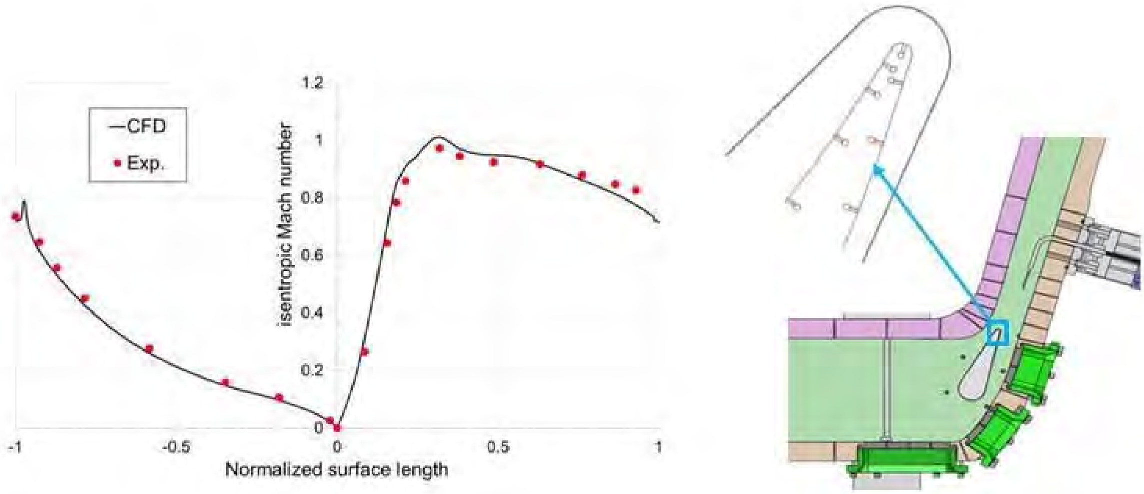

Figure 4-6. *Predicted and Measured Mach Number Distribution on the Airfoil Surface*

A kiel pressure probe traverse downstream of the test airfoil was also used to measure the exit total pressure distribution to establish a baseline for assessing airfoil profile losses and losses due to mixing of the film cooling jets. A typical wake profile from such downstream traverse measurement of the uncooled airfoil is shown in ***Figure 4-7***. Only the data in the loss core indicated by the blue-colored vertical lines in ***Figure 4-7*** is ultimately integrated to obtain an area-averaged downstream total pressure, pt2. The extent of such integration domain is guided by the CFD prediction. Since the upstream total pressure, ptg, is also measured in the rig, an uncooled loss can be defined as follows:

$$L_0 = \frac{p_{tg} - p_{t2}}{p_{tg}}$$

Equation 4

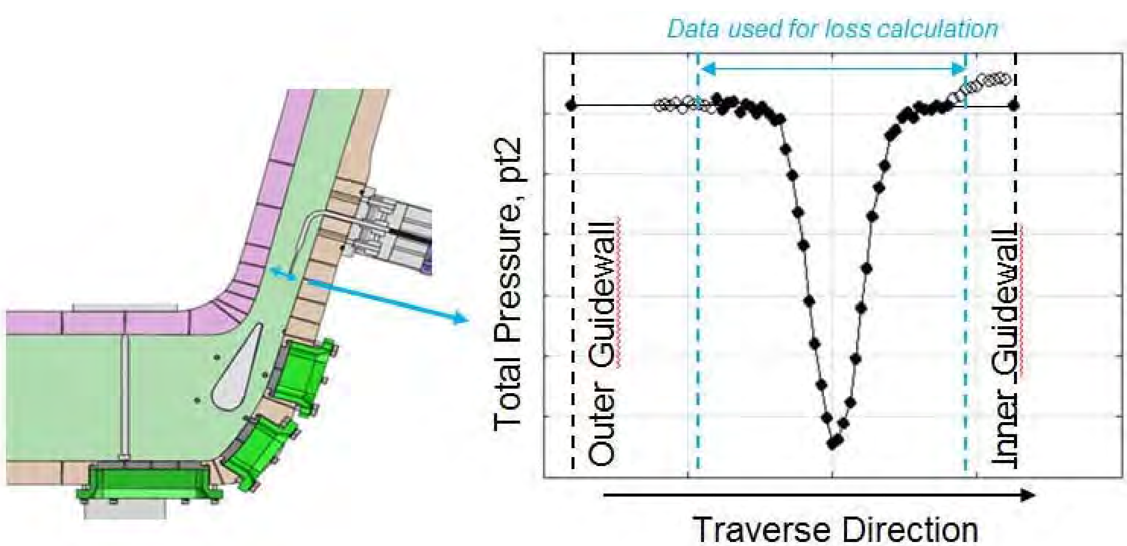

Figure 4-7. *Typical Total Pressure Distribution Measured Downstream of the Test Airfoil*

Measurements of the airfoil profile losses obtained from the uncooled airfoil (PTAP; no cooling holes) as well as the cooled airfoils at zero cooling flow condition (A1, A2) showed very good repeatability. Furthermore, the measured profile loss agreed with the loss predicted by CFD analysis.

4.7 SUCTION-SIDE COOLING

Measurements of the airfoil profile losses obtained from the uncooled airfoil (PTAP; no cooling holes) as well as the cooled airfoils at zero cooling flow condition (A1, A2) showed very good repeatability. Furthermore, the measured profile loss agreed with the loss predicted by CFD analysis. ***Figure 4-8*** presents the measured cooling losses, L_c, for the suction-side row SA (left). Results are plotted over a non-dimensional mass flow ratio, mc/mg. Since the total pressure in the cooling plenum, ptc, as well as the cascade and cooling massflows were also measured, a mass-weighted total pressure loss can be defined as follows:

$$L_c = \frac{(\dot{m}_g p_{tg} + \dot{m}_c p_{tc}) - (\dot{m}_g + \dot{m}_c) p_{t2}}{(\dot{m}_g p_{tg} + \dot{m}_c p_{tc})} - L_0$$

Equation 5

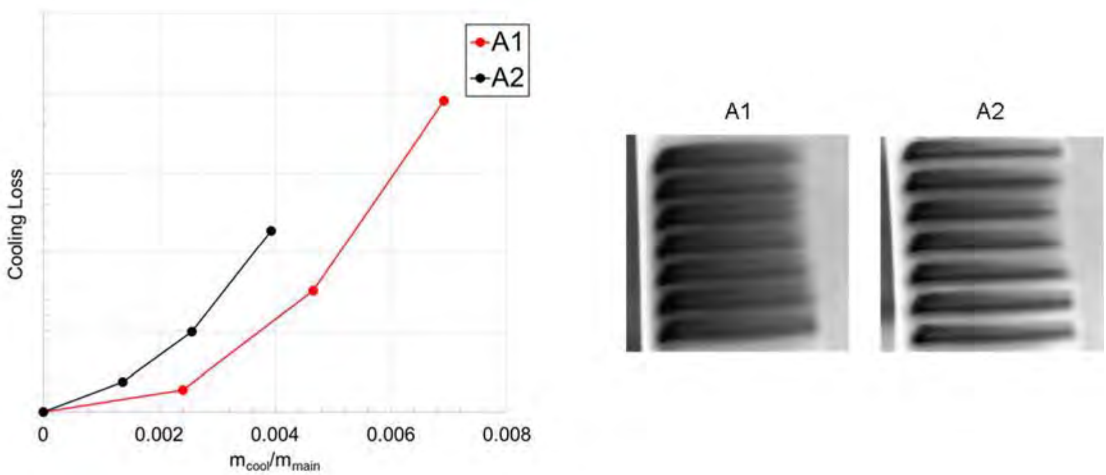

Figure 4-8. *Measured Cooling Losses for Suction Side Row SA (left), Raw IR Data From the Cooling Test at Medium Blowing Ratio, BR (right)*

Subtraction of the uncooled loss, L0, in this equation allows for the additional loss due to cooling to be isolated from the overall profile loss of the airfoil. It can be seen that for any given mass flow ratio, the advanced hole shapes (A2) cause an increased cooling loss compared to the standard shaped holes (A1). The raw IR data presented in ***Figure 4-8*** (right) shows the film-cooling traces on the surface of the airfoil downstream of the shaped and advanced cooling holes at a nominal blowing ratio. These film traces have been mapped to a CAD model of the airfoil for further post-processing and the calculation of overall film effectiveness. It was deduced that the film coming out of each advanced shaped hole in row SA has a wider radial footprint compared to the standard shaped hole. This wider film-footprint enables the film to cool a larger span section com- pared to the standard shaped hole. It can also be seen that there is a clear distinction of film traces coming out of each hole in row SA on airfoil A2 (advanced shaped) while the traces on A1 (standard shaped) are superposed together. This results in regions of lower film-effectiveness between the film traces from each hole on row SA on airfoil A2. Such regions of low film-effectiveness between each discrete cooling hole do not exist for the standard cooling hole row which are tightly spaced. In general, the film-effectiveness and loss results suggest that there is a difference in how the cooling jet mixes with the main gaspath air.

While the results presented in ***Figure 4-8*** show that the advanced shaped holes lead to higher losses, overall less cooling mass flow was required to cool the same surface area with advanced shape cooling holes. This is due to the difference in hole spacing discussed earlier. Accounting for these differences it was calculate that an overall benefit can be realized for the advanced configuration of airfoil A2. However, measurements of film effectiveness also indicate some regions of lower film-effectiveness for A2 which suggests that the hole spacing for the advanced holes might require slight adjustment. This may prevent the full benefit of flow and loss reduction to be realized. Still, the results emphasize the potential of the advanced shaped cooling hole to reduced overall cooling flow levels and improve thermodynamic cycle efficiencies.

4.8 PRESSURE SIDE COOLING

This section discusses the results obtained from testing film-cooling on the airfoil pressure side row PB at three different blowing rates on both airfoils A1 and A2.

The results show that for both hole geometries, the film-core size at the hole exit have is only marginally bigger for the advanced shaped hole compared to the standard shaped hole. As a result, there are larger regions of low film-effectiveness between each film trace on airfoil A2 compared to A1. This region of low film-effectiveness is also much bigger than that previously observed on the suction side of the same airfoil. In addition, the film-effectiveness contour plots also show that the film coming from the advanced holes attenuate faster downstream of the hole exit. Finally, the film from each hole lacks the radial distortion (two-lobed distribution) previously observed for similar holes on the airfoil suction side. Such differences in film distribution on the pressure side relative to suction side allude to a difference in secondary flow structure between holes located on the pressure-side and suction-side of an airfoil. As it is to be understood, the pressure gradients and local Mach number are different at the film injection location for row SA (suction side) and row PB (pressure side) which is likely to alter the jet-in-crossflow secondary flow structure.

Analogous to the suction-side results presented in ***Figures 4-8*** and ***4-9***, measured cooling losses, Lc, for the pressure-side row PB are presented in ***Figures 4-9*** and ***4-13***. ***Figure 4-9*** indicates that, similar to row SA, the advanced hole shapes of airfoil A2 result in increased cooling losses compared to the standard shaped holes of airfoil A1 for mass flow ratios greater than 0.003. For smaller coolant mass flow ratios, the losses are small and very similar between A1 and A2. The IR data also shown in ***Figure 4-9*** (right) for the medium blowing ratio and both airfoils. The measurements show that for both hole geometries, the film-core size at the hole exit have is only marginally bigger for the advanced shaped hole compared to the standard shaped hole. As a result, there are larger regions of low film-effectiveness between each film trace on airfoil A2 compared to A1. This region of low film-effectiveness is also much bigger than that previously observed on the suction side of the same airfoil. In addition, calculated film effectiveness results suggest that the film coming from the advanced holes attenuate faster downstream of the hole exit. The reduction in film effectiveness could be the result of the coolant jet lifting off the airfoil surface rather than staying attached.

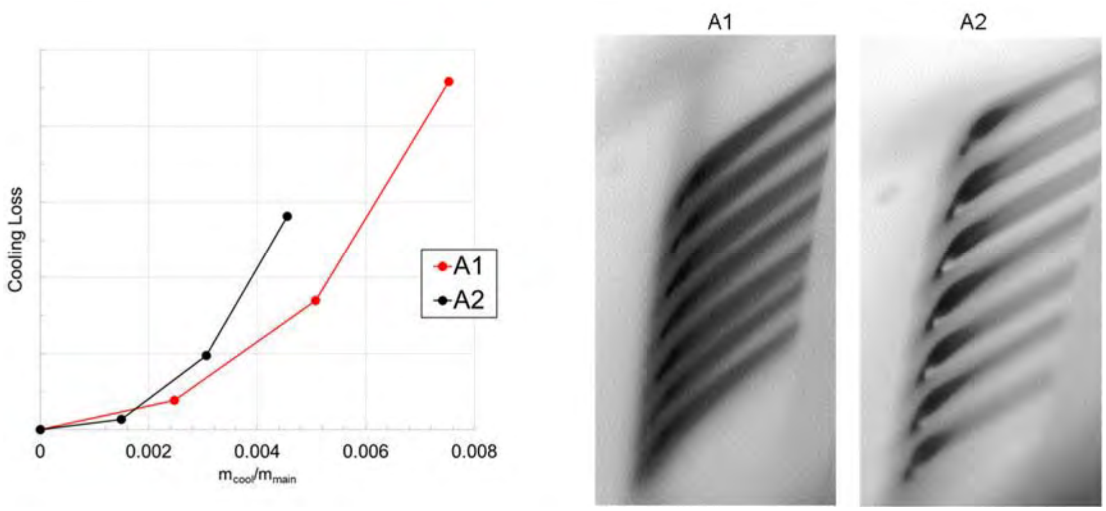

Figure 4-9. *Measured Cooling Losses for the Pressure Side Row PB (left) and Raw IR Data From the Cooling Test at Medium Blowing Ratio, BR (right)*

When comparing the overall surface area that is covered by film from the advanced hole shapes, the same conclusion can be drawn as for the suction-side film: airfoil A2 requires less cooling flow and incurs lower cooling loss for cooling the same surface extent when accounting for difference in cooling-hole spacing. However, since the IR data shows poor film-effectiveness for the advanced shaped hole on the airfoil pressure side, an overall benefit can only be realized after further optimizations of the cooling hole shape, and, in particular, the hole spacing. This would be required to arrive at the best aero-thermal solution that results in reduced cooling losses without compromising the surface film-effectiveness.

Airfoil A2 was selected for a repeatability test after the airfoil had been taken out of the cascade and then reinstalled at a later date. ***Figure 4-10*** shows good a greement and repeatability for the advanced pressure-side cooling hole shapes in airfoil A2, especially at low coolant mass flow rates.

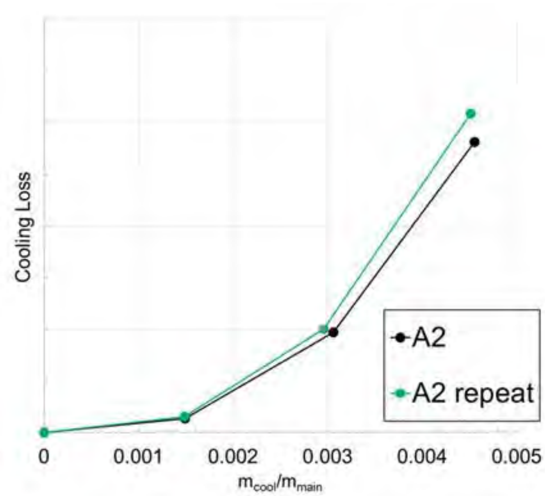

Figure 4-10. *Measured Cooling Losses for the Advanced Pressure-Side Cooling Holes of Airfoil A2 at Different Test Days*

4.9 SHOWERHEAD COOLING

This section discusses the film-cooling results for the leading edge row HA on airfoils A1 and A2. The showerhead cooling is typically required to cool the leading edges of HPT airfoils where the hot gases impinge on the airfoil surface resulting in one of the highest external heat transfer coefficients on an airfoil. Aerodynamic losses for showerhead cooling are believed to be low since the coolant film mixes with the hot gases at a low surface Mach number prior to being accelerated around the airfoil surface. At the same time, the low momentum of the mainstream gaspath air results in large blowing ratios for cooling holes in the vicinity of the stagnation point even at moderate supply pressures. As a result, the cooling jet is always at risk to blow off the airfoil surface, which results in poor film effectiveness.

Figure 4-11 presents the measured cooling losses for the leading-edge film of row HA. ***Figure 4-11*** (left) shows that the cooling losses associated with the two different hole shapes are very similar for small coolant mass flow rates (mc/mg<0.003). For larger coolant mass flow rates, increased losses are observed for the shaped showerhead holes compared to the round holes. The raw IR data also shown in ***Figure 4-11*** (right) indicates distinctly different film-effectiveness distribution for shaped holes, indicating that the cooling jet originating from the shaped leading-edge might lift off the airfoil surface. A similar effect, albeit less pronounced, can be seen for the round cooling holes. Overall, this trend is unexpected. The round holes were expected to show an increased propensity to jet blow off compared to the shaped holes. It is speculated that the reduced hole spacing for the round cooling holes promotes the interaction of adjacent cooling jets, leading to a more favorable blow-off characteristic compared to the shaped cooling holes that are spaced further apart.

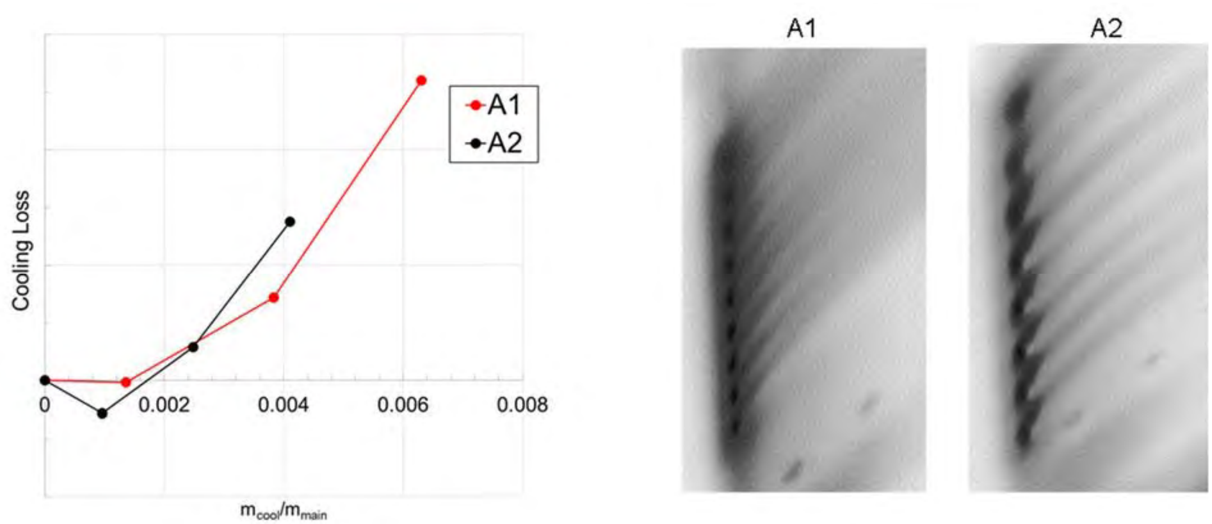

Figure 4-11. *Measured Cooling Losses for the Leading Edge Row HA (left) and Raw IR Data From the Cooling Test at Medium Blowing Ratio, BR (right)*

Film-cooling effectiveness results were reduced from the IR data for round (A1) and shaped (A2) showerhead cooling holes at various blowing ratios. At low blowing ratios, both hole types show relatively uniform film-effectiveness distribution across the airfoil span with attenuation in the streamwise direction towards the trailing edge. Increasing the blowing ratio results in a non-uniform distribution of film-effectiveness for round showerhead holes. Since the mainstream air in the leading-edge region has very low momentum, the high momentum cooling air jets from round holes sweep spanwise on the airfoil surface, especially at medium and high blowing rates. This superposition of film on one side of the airfoil span results in higher film-effectiveness downstream of the leading edge. On the contrary, film from shaped showerhead holes does not show this bias of film to one side of the airfoil span.

This is understood to be due to the lower momentum with which the cooling air exits the diffuser of the shaped cooling hole and therefore immediately swept downstream by the mainstream air.

Due to a difference in hole spacing, the same surface area on the airfoil is cooled with less coolant air for airfoil A2 compared to airfoil A1. While overall cooling loss levels are similar, the shaped showerhead cooling configuration does not lead to improved cooling effectiveness. However, as stated before, these measurements demonstrate sufficient sensitivity to cooling hole shape and its effect on both aerodynamic losses and film-effectiveness to support the theory that there exists an aero-thermal optimum for which the airfoil surface is cooled with reduced coolant mass flow and reduced mixing losses.

4.10 CONCLUSIONS

Single-element cascade testing was carried out under the FAA CLEEN II contract to investigate the aero-thermal performance associated with film cooling of a modern, low heat-load airfoil geometry. The design configurations included a variety of cooling hole shapes located at key locations around the airfoil. Highly resolved measurements of cooling film effectiveness and aerodynamic loss were obtained for standard round and shaped cooling holes as well as advanced cooling hole shapes. The advanced shapes had been developed and optimized for cooling a flat-plate geometry and were previously tested in a PSU low-speed, flat plate test facility. The SEC tests, however, were conducted at relevant operating conditions (Reynold's number, Mach number) emulating an engine take-off condition.

For all cooling rows (suction side, pressure side, showerhead) the measured data suggested that cooling losses increased for the advanced hole shapes. However, at the same time it was recognized that the same airfoil surface area was cooled with less cooling air for the advanced hole shapes. Accounting for these differences suggested that an overall reduction of cooling flow could be achieved to protect a given airfoil from the hot gaspath air. Even without improvements to film effectiveness and mixing losses, the reduced cooling air requirement would result in significant thermodynamic cycle efficiencies. Simultaneously measuring the quantities that are important to assess durability and aerodynamic performance is key to achieve that goal.

Ultimately, the SEC test also successfully generated a comprehensive benchmark data set that can be used to validate state-of-the-art CFD tools. Since CFD is used for cooling-hole optimizations, these validation activities play a key role in improving solver predictive capabilities and further developing advanced cooling technologies. Moreover, CFD will be exploited to enhance the understanding of physical mechanisms associated with different cooling hole shapes.

5. OVERALL SYSTEM LEVEL BENEFITS

The ultimate motivation for the component improvements under the CLEEN program is engine performance benefit at the system level. The PW1100G-JM performance model shows baseline performance compared to performance with the benefits of the compressor and turbine technologies mentioned in the previous sections.

The assessment is performed at ADP, which is cruise thrust, 35,000 ft Alt/0.78 Mach/ISA temperature. These benefits combined result in 1.4% reduction (improvement) in specific fuel consumption at ADP.

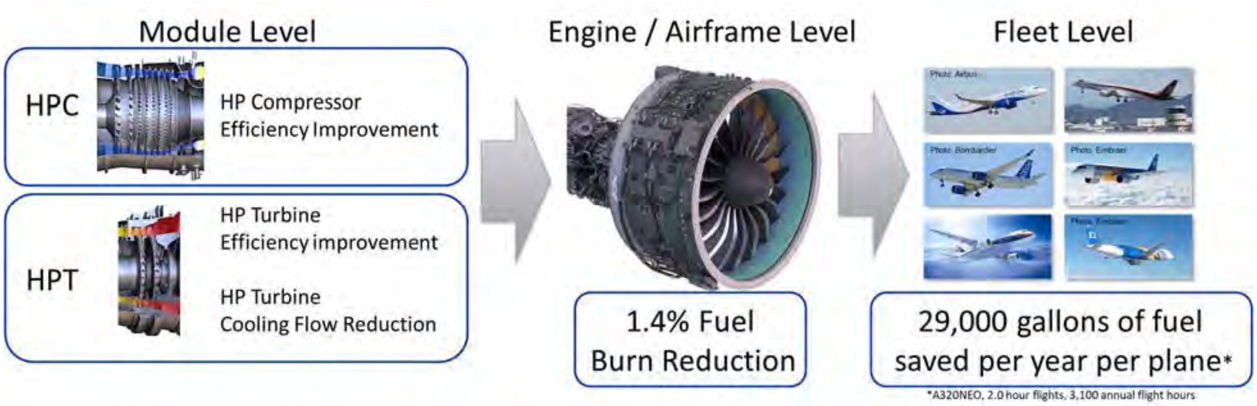

Figure 5-1. *CLEEN II Technologies System Level Impact*

Based on the A320neo average flight of 2 hours and the average number of hours flown in one year, the 1.4% cruise SFC improvement would save, on average, 29,000 gallons of fuel per year per airplane.

The turbine cooling flow reduction significantly contributes to the overall benefit, which might be less intuitive than that of the component efficiency increases. Engines bleed air from the high compressor to secondary air pipes to cool HPT vanes and blades. Since cooling air circumvents combustion. The HPT *tech blade* achieves the same component life in the hot environment with less cooling flow, improving the thermal cycle efficiency. Future system analysis work might show other advantages of how cooling flow reduction technology can contribute to system metrics:

1. Hold flow same as baseline and reduce maximum temperature at the airfoil to improve time on wing.
2. Bleed the same flow, reducing flow to the HP turbine, but increasing cooling flow to the LP turbine.
3. Improve compressor stability by possibly redistributing the loading in the HPC with the reduced bleed flow.

6. FUTURE APPLICATION DISCUSSION

P&W is pleased to collaborate with the FAA and their objective to develop continuous lower energy, emissions, and noise technologies for civil subsonic airplanes under the CLEEN initiative. The successful CLEEN I and CLEEN II programs have permitted P&W to develop, design, and validate advanced turbofan engine technologies that are aimed at impacting multiple current and future product lines by reducing the noise, emissions and fuel burn of the current generation of the GTF engine, as well as the next generation of GTF engines.

The recently certified GTF engines already delivers world-class capability in fuel burn, emissions, and noise. The technology portfolios developed under CLEEN I, II and proposed under CLEEN III are projected to continue improving on this state-of-the-art capability to deliver even more performance, noise reduction relative to the Stage 5 aircraft noise standards, nitrogen oxide (NOx) reduction, nonvolatile particulate matter (nvPM) reduction and additional fuel burn reduction. The proposed CLEEN III initiatives, when integrated with the UHB ratio GTF propulsor developed under the FAA CLEEN I program, and core technologies developed under the FAA CLEEN II program,will deliver 26 percent fuel-burn reduction (FBR), relative to a Year 2000 best-in-class aircraft, such as the Boeing 737-800, and achieve 18 EPNdB cumulative noise reduction relative to the Stage 5 aircraft noise standards (assuming approximately 3 EPNdB from airframe improvements). This represents a significant contribution to the achievement of the multiple FAA CLEEN subsonic transport aircraft goals and demonstrates the value of such programs for the country, its residents, the environment and our world.

CLEEEN II Technology, development and facilities, such as the PSU START test facility, has itself spun off additional technology development to continue efforts in defining alternatively manufactured highly efficient turbine blades with advanced cooling capability under the FAA ASCENT Program. This effort, contracted by the FAA to PSU, with support from P&W, will begin the learning and progressive technology development of low cost highly effective turbine blades of the future, while continuing educational development and university centers of excellence.

7. SUMMARY AND CLOSING STATEMENTS

In conclusion, the P&W FAA CLEEN II program was highly successful in demonstrating engine core thermal efficiency technologies with the GTF architecture.

The High Pressure Compressor and High Pressure Turbine rig testing made possible by collaboration between the FAA, PSU, and P&W, were able to demonstrate module level benefits utilizing full-scale hardware that are directly transferable to the GTF engine architecture.

For the HPC, P&W successfully demonstrated a product-like HPC core which in the end overachieved on estimated efficiency goals. P&W continued progress on the HPC design by testing the same core aero in both a ground and flight test engine bringing the Technology Readiness Level of that technology to TRL7.

For the HPT, P&W and the FAA assisted in enhancements to PSU's world-class START facility to enable the successful testing on novel technologies using new instrumentation and measurement methods in a representative engine environment. P&W was able to claim TRL 5 for durability technologies and TRL6 for aerodynamic technologies. The learning gained during the testing was directly transferred to ongoing design and manufacturing efforts for the GTF fleet.

In closing, P&W thanks the FAA for providing the funding and support in the successful execution of this highly successful program on-budget and on-time.

September/October 2021

FAA Safety BRIEFING

AIRPORTS and AIRSPACE

Federal Aviation Administration

U.S. Department
of Transportation

Federal Aviation Administration

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The Office of Management and Budget has approved the use of public funds for printing *FAA Safety Briefing*.

ABOUT THIS ISSUE...

The September/October 2021 issue of *FAA Safety Briefing* focuses on airports and airspace, which are integral parts of the National Airspace System's (NAS) infrastructure. Articles in this issue explore the value of our nation's vast array of public-use airports and their importance to the communities they serve. We also highlight some critical "rules of the sky," explore nearly a century of evolution in the NAS, and review some best practices for communicating with air traffic control.

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FAA Safety BRIEFING

The FAA Safety Policy Voice of Non-commercial General Aviation

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RAMPING UP

Over the past 18 months, we have experienced all kinds of COVID-related events. The pandemic has given us plenty of opportunities to develop new habits and skills, and to exercise words like "unprecedented." In far too many cases, though, it has deprived us of the ability to exercise other vocabularies and skills we once completed with ease. That list is long, but for purposes of this publication we will focus on the potential for lost proficiency in aviation activities.

If you are a regular reader of this magazine, you probably subscribe as well to some of the aviation community's excellent publications. Across the board, there has been a lot of ink (real and electronic) invested in reminders on how to regain and maintain proficiency. The *FAA Safety Briefing* team has long contributed to these efforts. If you are looking for a one-stop-shop review of flying fundamentals, take a fresh look at the January/February 2018 "Back to Basics" issue, along with the "Challenge and Response" theme in this year's January/February edition.

Competence and Confidence

Proficiency with flying skills is obviously important; after all, it's the first item in the well-known Aviate-Navigate-Communicate trifecta. But the muscle memory involved in piloting an aircraft might sometimes be easier to restore than the mental muscles involved in navigating and communicating, both in the air and on the ground. That's part of the rationale behind the *FAA Safety Briefing's* March/April 2021 "Enhancing Surface Safety" theme. This current issue builds on that work with a review of subject matter related to airports, airspace, and air traffic control (ATC) — to include a look at the elements comprising these fundamental parts of our nation's aviation infrastructure. On the subject of airports, we'll review some of the concepts you need to regain both competence and confidence to venture beyond the home 'drome once again. Among other things, the team takes a look at some of the app-based resources that can contribute to safe operations around new or dimly remembered destinations. We also note the 75th anniversary of this country's airport grant program, which helps support a crucial part of aviation infrastructure.

Venturing to different destinations involves navigating airspace in addition to the airports you visit. It's important to remember that airspace configurations can change with each chart cycle, sometimes quite substantially. Don't just assume you know the airspace you plan to traverse. Long before you head to the airport, sit down with a set of the most current charts and check carefully for any changes.

If you're going places again via airplane, it's likely that you'll need to communicate with ATC. ATC phraseology might not have changed much in the past 18 months. As we have previously observed, though, "Aviation-ese" really is a unique language with a distinctive grammar and vocabulary. Anyone who has studied a foreign language can attest to the fact that fluency fades fast when you don't use it on a regular basis. There's no substitute for real practice, which can include engaging with any of the many ATC simulation tools. To help you get started though, we will review the fundamentals of working with ATC. We think you will also enjoy the retrospective on how today's national airspace system, or NAS, evolved from its humble origins to the world-class service it offers today.

On a personal note: This will be my last Jumpseat column, because I am retiring after 27 years of federal service. It has been a privilege to "meet" you in these pages to share our passion for aviation, and for aviation safety. I wish you all the very best — blue skies and tailwinds!

LEARN MORE

Archived issues of *FAA Safety Briefing*
bit.ly/FAASB-Arc

AVIATION NEWS ROUNDUP

New Runway Safety Sim Released

A new animation to the Runway Safety Pilot Simulator stresses the importance of saying "unable" when pilots are not ready or able to accept a clearance from ATC.

14 CFR section 91.123 requires a pilot to follow all ATC clearances and instructions, but the final decision to act on ATC's instruction rests with the pilot. If a pilot cannot safely comply with any of ATC's instructions, the pilot should inform the controller immediately by using the word *unable*. Effective communication between controllers and pilots is essential when operating on airport movement areas.

Check out the animation library at RunwaySafetySimulator.com to learn more about this and other topics like eliminating distractions and avoiding runway confusion. The Runway Safety Pilot Simulator also contains three scenarios for both new and rusty pilots to practice taxiing on the airport movement areas, and to and from the runways, by listening to ATC instructions and selecting answers via decision-points.

New System to Track Space Launch and Reentry Vehicles in Near-Real Time

The FAA can now track a space launch or reentry vehicle in near-real time as it travels through the National Airspace System (NAS). This new capability increases safety for all airspace users and assists the FAA in efficiently managing air traffic during space operations.

The Space Data Integrator (SDI) prototype automates the delivery of vehicle-related telemetry data to the FAA Air Traffic Control System Command Center. This vastly improves the FAA's situational awareness of where the vehicle is as it travels to space or as it returns to Earth. In addition to existing tools, the FAA can also use SDI to manage air traffic more efficiently as a space operation progresses and address contingencies in the event of an anomaly during a mission.

Previously, the FAA had to close airspace for extended periods of time when a launch or reentry vehicle travels through the NAS. SDI allows the FAA to more dynamically manage airspace and minimize the impact on other airspace users.

In 2020, the FAA safely managed 45 space launches and reentries into the NAS, the most in the agency's history. For 2021, that number could exceed 70. Go to bit.ly/AirspaceIntegration for more information.

SAFETY ENHANCEMENT TOPICS

Please visit bit.ly/GAFactSheets for more information on these and other topics.

SEPTEMBER

Service Bulletins and the Aircraft Owner —
Understanding the importance of complying with a manufacturer's Service Instructions and Bulletins.

OCTOBER

Pilots and Medication —
Understanding how drugs can compromise a pilot's ability to control the aircraft.

UAS by the Numbers as of August 2021

11.5M+: Airspace lookups using the new B4UFLY mobile app
238,571: Total remote pilots
733,159: Total LAANC airspace authorization requests received
514,094: Online recreational UAS registrations
351,244: Online part 107 registrations
868,838: Total UAS registrations, including 3,500 paper-based recreational and part 107 registrations.

All Recreational UAS Operators Required to Take Test

In June, the FAA announced the selection of 16 organizations as FAA-approved Test Administrators (TAs) of The Recreational UAS Safety Test (TRUST). TRUST meets the congressional requirement, under the FAA Reauthorization Act of 2018 (49 U.S.C. 44809), for recreational flyers to take and pass an aeronautical knowledge and safety test. It was developed with input from various segments of the drone community including manufacturers, educational institutions, organizations, and individuals.

All recreational flyers (including children) operating under the exception for limited recreational operations of unmanned aircraft (49 USC 44809) must take and pass the test. This also includes part 107 remote pilots who choose to operate under 49 USC 44809. The knowledge check questions are correctable to 100% and the test is a "one and done" activity with no need for recurrent testing. Go to bit.ly/FAATRUST for more information on this free test.

New Air Force Commercial Space Agreement

The FAA and the Department of the Air Force signed an agreement aimed at eliminating red tape while protecting public safety during commercial space activities at ranges operated by the U.S. Space Force.

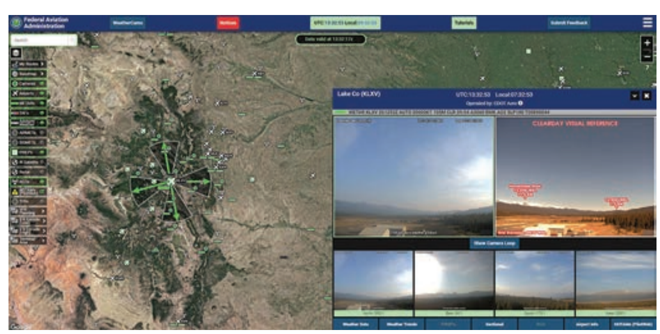
The agreement recognizes common safety standards for FAA-licensed launch and reentry activities that occur on, originate from, or return to Cape Canaveral Space Force Station in Florida and Vandenberg Space Force Base in California. It also removes duplicative processes and approvals for the U.S. commercial space sector.

Under the agreement, the FAA will accept the Space Force's ground safety rules and other safety processes, analyses, and products as long as they satisfy FAA regulations. The Space Force will accept FAA licensing decisions and generally will not impose its own requirements for the flight portion of a launch or reentry.

In 2020, the FAA licensed 39 commercial space launches, the most in the agency's history. Of those, 24 occurred at, and were supported by, these two U.S. Space Force ranges. For more on the agreement, see bit.ly/CommercialSpaceNews.

New Weather Cameras Coming Online

Ten new Colorado weather camera sites went live on the FAA Weather Camera website (weathercams.faa.gov) in June. Colorado now has 23 weather camera sites across the state. The Weather Camera (WCAM) program is working with state departments of transportation (DOTs) to install cameras and integrate images onto the FAA weather camera website. The WCAM program shares the design and technology for operating the cameras with state DOTs who install, own, and maintain the camera systems under cost reimbursable agreements.



The Colorado DOT has cameras situated in some remote areas of the state, including mountain passes that rise above 11,000 feet, which puts the cameras in a good spot to view snowpack conditions. Recently, the Colorado DOT installed cameras on many 13,000-foot mountain top weather stations where they were already monitoring weather conditions to aid pilots in navigating the passes.

The WCAM program is also working with helicopter medivac operators in several states to add cameras at hospital heliports that may lead to the development of special procedures to support these operations with weather cameras as part of the solution. The program plans to loan camera systems for one year to operators at three locations, one in Michigan and two in Mississippi, to conduct analysis of camera performance and create guidelines for other locations. Similar to the concept with state DOTs, after a one-year test period, the operators will purchase and maintain their own systems while the WCAM program will process, format, and publish images on the FAA weather camera website.

Visit weathercams.faa.gov to learn about new functionality, including a layer menu that allows for customization of icons displayed, keeping frequently used weather products at hand.

ON THIN AIR

Hypoxia (decreased oxygen reaching tissues) is an inherent risk for many in aviation, but there is training as well as regulatory requirements designed to mitigate it.

Pilots who operate pressurized aircraft capable of flight above FL250 are subject to the requirements of 14 CFR section 61.31(g). This regulation ensures that, with certain exceptions, pilots are trained to recognize hypoxia, decompression sickness, and the duration of consciousness at different altitudes. While the training is a one-time requirement, we encourage pilots to regularly reacquaint themselves with these subjects even if not mandated by their employer or insurance company. Note that the U.S. military requires that many of its pilots receive a full day of training, including a chamber ride, every five years in addition to initial training. We encourage pilots to consider at least some of the training covered under section 61.31(g), even if you're not subject to those requirements. Hypoxia can occur at altitudes well below FL250 and some pilots routinely fly unpressurized aircraft above FL250.

> **HYPOXIA IS AN INHERENT RISK IN AVIATION, BUT THERE ARE REGULATORY REQUIREMENTS DESIGNED TO MITIGATE IT.**

We also recommend hypoxia training for air traffic controllers. Many pilots have been helped by a controller who recognized that a pilot had hypoxia symptoms.

Some pilots believe that living at a higher altitude offers significant protection from hypoxia. This is partially true. Without question, someone who lives at 9,000 feet will handle an excursion to 12,000 feet better than someone who lives at sea level. However, this benefit rapidly decreases and is subject to individual variability.

So what exactly are the applicable regulations? For the general aviation pilot, 14 CFR section 91.211 applies. While most of us are familiar with the need for oxygen above a cabin pressure altitude of 12,500 feet mean sea level (MSL) for flights over 30 minutes and all flights above 14,000 feet MSL, there are additional rules for pressurized aircraft. For commercial operations, 14 CFR sections 121.327, 121.329, 121.331, 121.333, and 135.89 apply. Note that 14 CFR section 121.333(c)(3) was changed, effective May 23, 2020, to comply with section 579 of the 2018 FAA Reauthorization Act.

Many FAA handbooks discuss hypoxia. In addition, the FAA offers a number of other hypoxia training tools, including an advisory circular (AC) 61-107B CHG 1, *Aircraft Operations at Altitudes Above 25,000 Feet Mean Sea Level or Mach Numbers Greater than .75*; videos (e.g., bit.ly/FAATVHypoxia); Aeromedical Safety Brochures; and an in-person, one-day course in Oklahoma City. The latter includes training in either the altitude chamber or the PROTE (portable reduced oxygen training enclosure). Both expose the participant to an oxygen level equivalent to FL250. In the altitude chamber, the atmospheric pressure is reduced, demonstrating attendant effects on the ears, sinuses, etc. The pilot experiences both controlled (normal) ascent and a rapid decompression, but it can expose the participant to a small risk of decompression sickness. Contact the FAA physiology section at (405) 954-4837 for further details.

A newer, alternative method of demonstrating hypoxia is to have the participant breath air that has a lower percentage of oxygen. A quick internet search will show a number of commercial providers who offer this training. The FAA version, PROTE, is offered both in Oklahoma City as well as at events like AirVenture and Sun 'n Fun. Since our demand typically exceeds our availability, we are now exploring the possibility of purchasing an additional PROTE system. In the meantime, fly safe and use oxygen before you think you might need it.

Dr. Susan Northrup received a bachelor's degree in chemistry and a medical degree from The Ohio State University, as well as a master's degree in public health from the University of Texas. She is double board certified by the American Board of Preventive Medicine in Aerospace Medicine and Occupational Medicine. She is a retired U.S. Air Force colonel and a former regional medical director for Delta Air Lines. She is also an active, private pilot.

HYPOXIA

The scenery is often spectacular when flying close to the ground, but there are many advantages gained by flying at higher altitudes. Communication improves, as does navigation (other than GPS). Convective activity often decreases. Flight visibility (if out of the clouds) and true airspeed both benefit from higher altitudes. But these benefits come at a cost.

As one ascends, the ambient pressure decreases. On average, it decreases one inch Hg for every 1,000 feet up to 18,000 feet. The rate of decrease is not linear, although close. From sea level (at 29.92 inches Hg on a standard day), pressure decreases by half to about 14.9 inches Hg at 18,000 feet. As pressure decreases, gas expands. That includes the gas in your intestinal tract, sinuses, and ears.

This is not an issue if the pressure can be relieved. If blocked, though, incapacitating pain can result. We therefore recommend not flying with a cold or congestion, even if you're asymptomatic on medications. Gas introduced from medical procedures, even dental work, will also expand and might not have an escape route. I highly encourage discussing these issues with your treating physician (or, even better, your AME) before getting into an aircraft (personal or commercial).

In addition to pressure, the amount of available oxygen also decreases when you ascend. Even though the percentage of oxygen in the atmosphere is nearly constant at 21%, the amount of pressure is less, resulting in one half the amount of oxygen at 18,000 feet than at sea level. This is typically not a problem for someone young and fit, but most risk factors for decompression sickness (DCS) also

increase the risk of hypoxia (below). Use of supplemental oxygen is highly recommended above 5,000 feet, especially at night. 14 CFR section 91.211 outlines the legal requirements, but these are minima. Note also that the nasal cannula, preferred by many pilots, is inadequate for the higher altitudes. See Oxygen Equipment at bit.ly/OXYEquip (PDF).

REMEMBER THAT HYPOXIA IMPAIRS YOUR ABILITY TO RECOGNIZE THAT YOU ARE IMPAIRED.

Oxygen is carried in the blood primarily on the hemoglobin molecule (98%) with some directly absorbed into the blood (as it is in water). Each hemoglobin molecule carries four oxygen molecules, each progressively bound more tightly. The whole dissociation curve is non-linear and can shift from more tightly bound to less tightly. Factors that favor the latter include increased carbon dioxide, acidity, an increase in 2,3 DPG (an organic compound involved in O_2 movement), and heat. Of interest, these factors increase with exercise, which makes sense as that's when O_2 demand is highest.

Factors that adversely affect the oxygen carrying capacity of blood include: smoking, anemia (even though the pulse oximeter can remain normal), abnormal hemoglobin (sickle cell disease, thalassemia), etc. Prolonged sitting can also lead to impaired oxygen delivery (stagnant hypoxia).

For those pilots who SCUBA dive or snorkel, we recommend no flying after SCUBA for at least 24 hours, whether there was a mandated decompression stop or not. The risk of DCS increases with the depth, bottom time, and number of dives. Other risk factors include age, fitness, obesity, smoking, sleep loss, dehydration, alcohol and other drugs, some heart defects, cold water diving, and lung disease. Flying at low altitude or in a pressurized cabin does not eliminate the risk. I personally have seen divers develop DCS after driving over a 3,200-foot pass following several dives at sea level. When diving, consider safety stops even when not mandatory, stay hydrated, and maximize the surface interval. Note that skin diving, while safer than SCUBA, is not risk free. Repetitive deep dives while holding your breath can increase nitrogen build up in blood and tissues; DCS can result.

Remember that hypoxia impairs your ability to recognize that you are impaired. The best defense, other than supplemental oxygen, is to know your personal symptoms. In this issue's Aeromedical Advisory, Dr. Northrup addresses some of the available training.

Leo M. Hattrup, M.D., received a bachelor's degree from Wichita State University, a master's in public health from Harvard University, and a doctorate from Vanderbilt University. He is retired from the U.S. Air Force in which he spent the majority of his career in aerospace medicine. He is board certified in aerospace and occupational medicine. He is a certificated flight instructor and enjoys flying airplanes, helicopters, and gliders.

Look Listen FOCUS

LIVES ARE AT STAKE!

- **IT CAN HAPPEN TO YOU:** When you're approaching an airport that has a set of parallel offset runways, you may accidentally land on a different runway than you were originally cleared for.
- **THE FIX:** During pre-flight, remind yourself of possible landmarks that will help you clearly identify the runways. Have your passengers help pinpoint the correct runway!

Federal Aviation Administration

For additional runway safety education, take the AOPA Air Safety Institute's Runway Safety online course at www.airsafetyinstitute.org/runwaysafety.

From SHRIMP BOATS *to* SATELLITES

The Evolution of the National Airspace System

By Tom Hoffmann

It's a sweltering summer afternoon in 1929 at St. Louis Lambert Field. Peering out from under the shade of a beach umbrella perched alongside the airport tarmac, mechanic and barnstormer pilot Archie League carefully scans the sky. While manning his makeshift control tower — *a wheelbarrow* — League patiently waits to direct aircraft to and fro with a pair of signal flags at the ready. It is hard to imagine, but in the late 1920s this crude operation represented the extent of air traffic control services.

League's efforts as a pioneer air traffic controller, while venerable, stand in stark contrast to how air traffic control (ATC) keeps aircraft safely separated today. More than 90 years later, today's National Airspace System (NAS) is among the most complex in the world, supporting roughly 5,000 aircraft traversing the skies at any given moment during peak periods (pre-pandemic) and more than 19,000 airports across the nation. At the heart of those operations are the 14,000-plus air traffic controllers who work in concert with a vast network of navigational equipment to keep our skies safer than they have ever been. That is no small accomplishment given the numerous changes the aviation industry has experienced over the last century. As we continue to embrace the safety-enhancing benefits of the FAA's Next Generation Air Transportation System initiative, there is much we can learn from previous generations whose innovative thinking enabled them to adapt to changing environments and affect safe change in the NAS.

Pioneer air traffic controller Archie League.

Can You Hear Me Now?

According to early airspace pioneer Glen Gilbert, air traffic control has one basic objective: to prevent a collision between two aircraft. That simple creed became increasingly difficult to uphold with the voluntary "see and be seen" policies in place during aviation's early 1930s boom. Gilbert was among the first to emphasize the need for not only a more structured system, but also one that mandated participation to remain effective. One of the limiting factors at this stage was radio technology, which, as its popularity grew, eventually phased out the bonfires, signal flags, and light gun signals previously used as communication tools. Direct radio links also proved useful as they would later replace the cumbersome relay of one-way telephone and radio calls among the pilot, dispatcher, and controller.

Further complicating the early days of ATC was the lack of engineering support from the U.S. Department of Commerce. This meant controllers had to be inventors as well as guardians of the sky. Early home-grown ideas that helped controllers perform their jobs included telephone recording equipment, flight sequencing boards, and small wooden markers dubbed "shrimp boats" that were pushed around an airspace map every 15 minutes to keep track of aircraft positions.

Since the science of airspace management was literally starting from scratch, there was also a pressing need for system planning contributions. Earl Ward, regarded by many as the father of air traffic control, is credited with many of those innovations. Ward conceived the idea of establishing a system of Air Traffic Control Centers. The first three were located in Newark, Cleveland, and Chicago. These centers, along with the procedures Gilbert helped develop for the industry's first ATC manual, provided the building blocks for what was becoming a globally recognized air traffic management system.

In the years that followed, aviation continued to grow, spurred by World War II efforts to build more airports and produce bigger, faster, and more advanced aircraft. While some may have questioned the ability of U.S. airspace to accommodate the anticipated gridlock of private, commercial, and military users, Gilbert maintained that an ATC system should not discriminate but permit access to *all* categories of airspace users. He dispelled the notion of what were considered "incurable limiting factors" in his book *Air Traffic Control: The Uncrowded Sky*. "It is the system that is crowded, not the skies," said Gilbert. "In other words, our objective must be to learn how to effectively utilize the virtually unlimited capacity of our Uncrowded Sky."

The advent of radar technology helped do just that, and by the early 1950s, aircraft movements were now visible on electronic scopes. Aided later by computers, ATC was soon able to follow those blips on more sophisticated three-dimensional tracks. In the following decades, airspace safety made tremendous strides with enhancements in the areas of automation, weather, navigation, avionics equipment, and more. These improvements became effective tools in handling the growing volume and diversity of traffic and provided both ATC and pilots greater situational awareness, a key ingredient to a safe NAS.

> **Gilbert maintained that an ATC system should not discriminate but permit access to *all* categories of airspace users.**

Recalculating . . .

Gilbert had the right idea when he predicted the final challenges for a future generation of effective air traffic management would be the need to factor in the complete picture of all its individual elements. That means considering everything from the framework of regulations and procedures to the end-user pilots and controllers. Based on principles of integration and collaboration, the FAA's satellite-based NextGen transition takes a more holistic approach to airspace safety and represents an entirely new and forward-looking way of doing business.

In 2021, the impact of NextGen is clearly visible with NAS users who regularly reap its many benefits. Setting the stage for today's capabilities were accomplishments focused on the Automatic Dependent Surveillance-Broadcast (ADS-B) system. One of six transformational NextGen technologies, ADS-B transmits the location of aircraft to controllers and other ADS-B equipped aircraft with a faster update rate than radar. Aircraft equipped with ADS-B In avionics can receive traffic information, enhancing pilot situational awareness. Aircraft able to receive signals on 978 MHz can also receive weather and aeronautical information in the cockpit. Pilots flying in properly equipped aircraft in ADS-B coverage areas can also see the location of surrounding aircraft that are equipped with ADS-B or transponders in a 15-mile radius, 3,500

feet above or below their current altitude. The nationwide infrastructure for ADS-B was completed in 2014. This means that the nation's airspace system now has satellite-based coverage wherever radar coverage exists — as well as in some areas that lack radar coverage, such as certain low-altitude airspace, the Gulf of Mexico, and Alaska. Real-time ADS-B is also the preferred method of surveillance for air traffic control in the NAS.

We are now one and a half years beyond the ADS-B Out equipage mandate for those operating in designated airspace and, as of July 1, 2021, over 146,000 U.S. aircraft have been properly equipped. You can read more about the benefits and capabilities of ADS-B at www.faa.gov/go/equipadsb.

Another critical component of NextGen is Data Communications, or Data Comm, which is a digital communications platform that uses electronic messages between pilots and controllers. Digitally delivered clearances have already improved accuracy by eliminating misheard communications and confused call-signs, and reducing radio congestion. Data Comm is currently operational at 62 control towers and three Air Route Traffic Control Centers in the United States, with more on the way.

The NextGen initiative is nearing completion. While there is still some way to go to realize its full potential, the growing frequency of NextGen success stories is a sure sign that it has made a lasting impact on the safety of the NAS.

Sharing the Skies

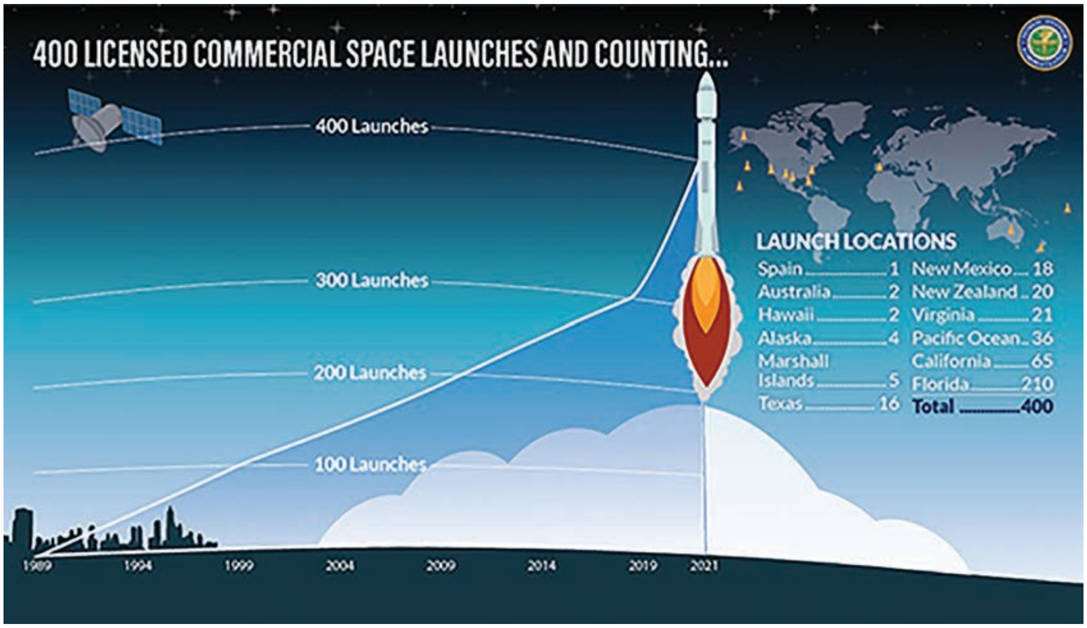
Despite recent uncertainties on COVID 19-related slowdowns and their long-term impact on the economy, the FAA's latest Aerospace Forecast projects that operations at FAA and contract towers will grow, albeit modestly, at 0.9% per year over the next 20 years, with commercial and business aviation as the primary drivers. In addition to this regular growth, NAS users are also learning to share the skies with new entrants. Developing at breakneck speeds are the many commercial applications of Unmanned Aircraft Systems (UAS) or drones, ranging in size from a small bird to a medium-size airliner.

With the newly published Remote Identification and Operations Over People rules, the FAA has taken a giant leap towards expanding NAS integration efforts and allowing for more routine operations for certain small UAS, all without compromising safety. This includes operations that are beyond visual line of sight (BVLOS). A newly formed UAS BVLOS Aviation Rulemaking Committee (bit.ly/3yUDGgg) is further exploring this concept and aims to provide recommendations for performance-based regulatory requirements to normalize safe, scalable, economically viable, and environmentally advantageous UAS BVLOS operations that are not under direct air traffic control. A first report is expected by early 2022.

> **Whether using bonfires, shrimp boats, or high-tech satellites, the FAA's mission has always focused on providing the safest, most efficient aerospace system in the world.**

Taking NAS Operations to New Heights

Another rapidly expanding area is *literally* out of this world. The FAA's Office of Commercial Space Transportation, which licenses and regulates U.S. commercial space launch and reentry activity, recently recorded its 400th commercially licensed launch and is forecasting the number of commercial space operations to meet or exceed 50 in 2021. It's possible that number could reach 100 or more per year in the not-too-distant future once space tourism really takes off. So far, the FAA has also issued licenses for 12 commercial spaceports located in six states, with six additional spaceports in the process of obtaining a safety approval. To bolster support in this arena, the U.S. Department of Transportation (DOT) recently renewed a charter with the Commercial Space Transportation Advisory Committee (COMSTAC) to extend to June 2023. This 22-member committee provides valuable input to DOT and the FAA on space operations, including expert advice on safety and technology. Read more on COMSTAC here: bit.ly/COMSTAC.



Another exciting chapter in the evolution of the NAS involves the growing advancement of Unmanned Aircraft System Traffic Management (UTM) as well as Advanced and Urban Air Mobility (AAM/UAM). The latter is a developing ecosystem of transportation that envisions the use of highly automated aircraft that transport passengers and cargo in urban and suburban areas, and includes longer range operations for both commercial and recreational purposes. The cornerstone for the type of situational awareness required for these operations to be safely performed is UTM. You can read more about these game-changing concepts in our May/June 2021 "Sharing the Skies Safely" issue or at bit.ly/UTMMgmt. NextGen's open and collaborative approach towards problem-solving is designed to effectively factor in these and other challenges that might arise during the next phase of airspace evolution.

You Are Cleared for the Approach

To say the nation's airspace has witnessed a tremendous amount of change over the last century would be quite an understatement. Whether using bonfires, shrimp boats, or high-tech satellites, the FAA's mission has always focused on providing the safest, most efficient aerospace system in the world. Even in the early days of airspace development, we can see the great deal of planning, coordination, and out-side-the-box thinking needed to overcome challenges and maintain safety in the NAS. Those same principles are alive and well today and are among the key tenets of NextGen, a model of safety and efficiency that promises access to all categories of users. That's something the founding fathers of ATC would surely be proud of today.

Tom Hoffmann is managing editor of *FAA Safety Briefing*. He is a commercial pilot and holds an A&P certificate.

LEARN MORE

FAA National Airspace System
faa.gov/air_traffic/nas

FAA NextGen Website
faa.gov/nextgen

Advisory Circular 20-172, *Airworthiness Approval for ADS-B In Systems and Applications*
bit.ly/AC20-172

Information Sheet on Archie League, the First Air Traffic Controller
bit.ly/ArchieLeague

(Don't) Drop the Mic!

Take Our Quiz to Sound Like a Pro on the Radio

By Jennifer Caron

Two mics, one goal. Clear communication between pilots and controllers creates the shared situational awareness that's needed to keep you and your fellow flyers safe on the ground and in the air. But for some, talking to air traffic control elicits full-on panic and fear. A famous quote by comedian Jerry Seinfeld sums it up nicely — "People's number one fear is public speaking. Number two is death. *Death* is number *two*? Does that sound right?!"

If you haven't mastered the language of aviation, then yes, it can be downright nerve-wracking when you key the mic! But remember — air traffic control (ATC) is working to separate and sequence aircraft to keep everyone safe. Together, you and ATC are a team sharing the same mindset when it comes to safety. That's why it's important to learn the correct lingo, know and understand what certain words or phrases mean, and *practice, practice, practice* the proper phraseology you need to use when talking to ATC.

So how can you learn to "speak ATC?" For starters, take our quiz. You'll not only find the answers below, but you'll also get helpful tips and no-nonsense input from air traffic controllers, plus free, or low-cost resources you can use to learn, stay sharp, calm nerves, and practice your way into long-term success.

Scenario 1: Rollin' Off the Runway

"Cessna 1234 Oscar, Metro Ground, Runway 21 Intersection Golf, taxi via Taxiway Kilo and Taxiway Victor. Expect a delay at the runway for traffic."

"Cessna 1234 Oscar, will taxi to Runway 21 at Intersection Golf via Taxiway Kilo and Taxiway Victor. We will expect a delay."

Pilot expects to use the delay for final preparations before takeoff when suddenly ATC is back.

"Cessna 1234 Oscar, Metro Tower, Runway 21 at Intersection Golf cleared for takeoff, traffic is on a four mile final."

Feeling rushed, the pilot accepts the clearance, even though he's not prepared to takeoff. He starts the departure roll in the wrong direction, veering off the runway onto the grass.

What should the pilot have said to ATC?

- **"Cessna 1234 Oscar, Roger"**
- **" Cessna 1234 Oscar, Unable"**
- **" Cessna 1234 Oscar, Wilco"**
- **" Cessna 1234 Oscar, Wasn't Expecting That!"**

Answer: **The answer here is: *Cessna 1234 Oscar, Unable.*** Remember, **the final decision to act on ATC's instructions rests with you.**

You don't have to accept the clearance. If you need more time, or if you're *unable* to comply, just say "unable." When in doubt, ask for clarification. Don't feel rushed or distracted and **remember to always use your call sign.** Controllers are prepared at all times to repeat, clarify, or give alternate instructions to help you. Watch this FAA video of a real-life event where saying "unable" could have prevented the incident: RunwaySafetySimulator.com.

Scenario 2: Roger That Affirmative

"Cessna 5432 India, do you have the airport in sight?"

If you can see the airport, how should you respond to ATC?

" Cessna 5432 India, Yes"

" Cessna 5432 India, Roger"

" Cessna 5432 India, Affirmative"

" Cessna 5432 India, Wilco"

Answer: Yes or No is not proper aviation phraseology. The correct terms are *"Affirmative"* for Yes, or *"Negative"* for No. *"Wilco"* is short for "I heard your message and I will comply." *"Roger"* means "received and understood." **Never use Roger to answer a yes or no question. The correct answer to this question is: *Cessna 5432 India, Affirmative.***

"Pilots tend to mix up 'roger' and 'affirmative' quite a bit," says Sarah Patten, Air Traffic Control Specialist at FAA Potomac TRACON. "If I'm trying to get a definite answer to a question (for example, do you have the airport in sight?), and they answer 'Roger,' that's basically the same as saying 'ok,' or 'I heard the question,' which doesn't make any sense," Patten explains.

Using "Roger," the conversation would go like this:

"Cessna 5432 India, do you have the airport in sight?"

"Cessna 5432 India, I heard the question."

"That clearly doesn't give me much of an answer," she continues, "or much confidence that they're going to wind up in the right place. Then I have to go back and ask the question again to make sure we're all on the same page."

One controller on Reddit wrote that when he hears a pilot say "Roger" as an answer to his yes or no question, he always radios back — "Is that an Affirmative Roger, or a Negative Roger?" **Always answer yes or no questions with Affirmative or Negative.**

Bonus Question:

"Cessna 5432 India, traffic one o'clock, two miles, eastbound."

What's your reply?

In this example, ATC's transmission is not a yes or no question, it's a traffic advisory. You should state whether you have the traffic in sight or "looking," and include the aircraft's position or identifier. **Your reply should be: *Cessna 5432 India, traffic one o'clock, in sight. Or Cessna 5432 India, looking for traffic.*** (See Scenario 3 for more on this topic.)

Scenario 3: Oh Say Can You See the Traffic?

"Cessna 5432 Oscar, traffic three o'clock, four miles, eastbound 3,000, Embraer jet inbound for Runway two-niner, report the traffic in sight."

" Cessna 5432 Oscar, looking for the traffic."

"Cessna 5432 Oscar, additional traffic nine o'clock, three miles, turning northeast bound is a Marchetti climbing out at 2,000 feet."

"Cessna 5432 Oscar, I have the traffic in sight, he's not a factor."

"Cessna 5432 Oscar, how is the traffic not a factor?! He's turning inbound and descending out of 2,700."

Which traffic did the pilot have in sight? The Embraer jet at three o'clock or the Marchetti at nine o'clock? Instead of saying "Looking for *the traffic*," or "I have *the traffic* in sight," what should the pilot have said to ATC?

Answer: ***The pilot should specify which traffic he has in sight by including either the aircraft identifier (Embraer or Marchetti) or the aircraft's position (three o'clock or nine o'clock) in the transmission to ATC.***

Shared situational awareness is key. Brevity is important, but controllers must know that you've heard the traffic advisory and that you completely understand the traffic picture.

"Any time you're flying in or out of a VFR airport, it's likely the controller will give you a traffic call on more than one aircraft," says Peter Sachs, a former controller currently working in the FAA's UAS Integration Office. "If a controller gives you two traffic calls and you say, 'traffic in sight,' does that mean you see both aircraft, or just one?" he asks. At Class D towers, controllers may issue general instructions to avoid traffic ("turn north"), but they can't issue radar vectors. "That doesn't mean you should ignore those calls just because you think you have the complete traffic picture," Sachs explains.

"It can be especially frustrating to make a traffic call for someone and get no response," says Patten. "I have no way of knowing if they heard what I said and are busy looking out the window, or if they didn't hear me at all. If a pilot is looking for traffic and doesn't have it in sight yet, that's helpful to know — 'Cessna 5432 Oscar looking for traffic' works well in that situation," she explains. "Also, a pilot telling me that they 'have the traffic on TCAS' (or 'ADS-B,' or 'the fish finder,' or any number of other things I've heard pilots call it) doesn't help me as a controller. If you don't tell me that you have the traffic in sight, I'm going to keep giving you traffic advisories until you actually see the other aircraft," she adds.

Consider the midair collision in Colorado this past May. The accident is still under investigation, but some information suggests that a misunderstanding of the traffic picture may have been a factor. The controller advised the Cirrus pilot of Metroliner traffic and he replied, "Have traffic in sight." The Metroliner was also issued an advisory to which he replied, "We're looking."

Do not ignore traffic calls or provide an ambiguous readback. **Make it a best practice to reply back to ATC using the aircraft's identifier or position.**

For example:

"Cessna 5432 Oscar, additional traffic, four miles to your north is a Metroliner for the parallel."

"Cessna 5432 Oscar, *Metroliner* traffic in sight.

"Cessna 5432 Oscar, traffic nine o'clock, Delta Airbus A320."

"Cessna 5432 Oscar, *traffic nine o'clock*, in sight."

Scenario 4: Stand By Me

"Metro Tower, this is Cessna 1234 India, holding short of Runway 21, ready for departure."

"Cessna 1234 India, Metro Tower, Stand By."

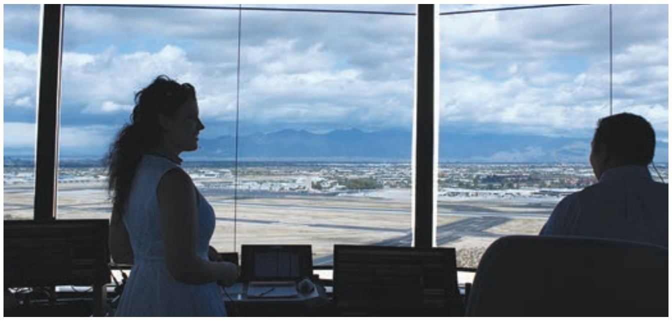
"Cleared for takeoff Runway 21, Cessna 1234 India."

Clearly, the pilot did not have clearance to proceed. But what does "Stand By" actually mean?

- **Clearance to Proceed**
- **Line Up and Wait**
- **Hold Short**
- **Wait**

Answer: "Stand By" means ***wait***. Monitor the frequency, we will re-establish contact. It does not deliver clearance. It is simply a way of saying, "I will get back to you soon," or "I'm too busy to answer you right now, but I will be right back." If ATC seems to have forgotten you, **never assume you have clearance to proceed**. When there is a break in transmissions, call again.

"If I say 'Stand By' to a pilot, I usually have something else that needs my attention before I'm able to add another airplane to whatever I've got going on," explains Patten. "Sometimes, whatever I'm dealing with that has me instructing a pilot to stand by may be going on behind the scenes. I may be coordinating something with another sector or facility, I may be trying to fix or find someone's flight plan, or I may be giving a relief briefing. There may be a moment or two of silence on a frequency after I tell someone to stand by, but it doesn't mean there isn't anything going on. I usually just need a minute or two to get something else settled before I have enough time to properly handle a new request," says Patten. She explains that a big part of being a controller is knowing your operational priorities (and your limits). Using "Stand By" helps keep things under control.



Scenario 5: I'm Listening

"Metro Ground, Cessna 2345 Oscar, FBO west parking with Information Echo, ready to taxi."

"Cessna 2345 Oscar, Metro Ground, Stand By."

"Standing by, Cessna 2345 Oscar."

"Cessna 2345 Oscar, Metro Ground, Go Ahead."

"Taxiing to Runway 21, Cessna 2345 Oscar."

True or False. Was the pilot cleared to proceed?

Answer: False. The pilot was not cleared to proceed. The phrase "Go Ahead" is only used as an instruction to proceed with your request or transmission. It is not used for any other purpose and does **not** deliver clearance to proceed.

"'Go Ahead,' says Patten, is one I find myself using quite a bit, and it means exactly what was mentioned: go ahead with your transmission, NOT go ahead and do whatever you want!"

Did you get all the questions right? Before you check out the resources below, make a point to contact your local FAA Safety Team (FAASTeam) Rep to see if there are any scheduled tower tours, or if one could be set up. You can meet some controllers (I promise they won't bite) and see how it all works. That's a great way to learn the right lingo and help push the fear out of push-to-talk.

Resources

1. **Online** controller-to-pilot platforms and software programs that you can use to train at home: vatsim.net, redbirdflight.com, pilotedge.net.
2. **Free** — liveatc.net, Pilot/Controller Glossary (bit.ly/FAAglossary), FAA Safety Team Course: Radio Communications Phraseology and Techniques (bit.ly/CommsPhraseology), "How to Become an Air Traffic Controller" on the FAA's The Air Up There podcast (faa.gov/podcasts).

Jennifer Caron is *FAA Safety Briefing*'s copy editor and quality assurance lead. She is a certified technical writer-editor in the FAA's Flight Standards Service.

Content Disclaimer: Products and services mentioned in this article do not constitute official endorsement on behalf of the FAA.

LEARN MORE

Check out more *FAA Safety Briefing* articles on this topic at bit.ly/FAASB-Arc:

- How to Talk Like a Pilot — Jan/Feb 2018
- Do You Suffer from Push-to-Talk Phobia? — Nov/Dec 2017
- No-Go on the Radio — May/June 2020

The Advantages of Adventuring

Using Airport Visits to Advance Skills (and Pilot Stories!)

By Susan K. Parson

One of the aeronautical experience requirements for an instrument rating is to log at least 50 hours of cross-country flight time as pilot-in-command (PIC). I initially chafed because I just wanted to get on with my flight training. I also found the prospect of accumulating 50 cross-country hours a bit daunting. To make it manageable, I took a sectional chart, drew circles with 50 and 100 nautical mile radii, and made a list of airports that landed (so to speak) in the zone.

Once I got started, I realized that many educational and proficiency benefits accrue from flying to unfamiliar airports. Though I had flown to a few during training for my private pilot certificate, most were new territory. The same was true when I participated in Virginia's Aviation Ambassadors Program (bit.ly/VAAviationAmbassadors), which incentivizes visits to the state's public-use airports.

Here are just a few of the great lessons learned from my quest.

Photo courtesy of the City of Chandler, Ariz.

Plans

Flight planning apps weren't a thing yet, so I did a lot of manual flight planning. The exercise of drawing and measuring the course line, calculating performance, evaluating weather/NOTAMs, and consulting the Airport/Facility Directory (now called the Chart Supplement) for the target airport's vital statistics solidified fundamental flight planning skills. Flying to unfamiliar airports sharpened both the competence and my confidence in pilotage, dead reckoning, and course intercepts and tracking.

Another great lesson was the experience of changing the plan for weather or operational issues that can arise. For example:

- A trip to a smaller airport on a typical summer day in the mid-Atlantic region gave me a whole new appreciation for the challenge of spotting an unfamiliar airport in thick haze. I also learned what 3-to-5-mile visibility really looks like.
- On a flight to an airport in Class C airspace, the controller abruptly canceled my landing clearance and gave me a vector to allow an airliner to zoom past. I then needed to use those ground school lessons in wake turbulence avoidance, make a last-minute runway change, and taxi through a concrete maze very different from the single-runway simplicity of my home airport.
- A scenic airport in mountainous terrain reinforced lessons about density altitude. Because its runway was also shorter than the one at home base, that airport also provided a good reminder of how important practical performance calculations are to safe operations.

People (and Pets)

One of the best benefits of venturing to different airports is meeting airport people. Like airplanes and airports, airplane people come in many shapes and sizes. The one thing they typically have in common is an outsized enthusiasm for aviation, airplanes, and fellow aviators. Friendly faces prevailed at even the bigger airports, but what fun to meet so many people whose idea of weekend fun includes hanging out at the local airport. These kind souls offer both encouragement and education on local flying conditions and quirks. I especially remember a small airport whose charmingly eccentric operator offered lunch (complete with homemade ice cream) that she served with a side of hangar flying stories to all weekend visitors.

Airport pets are special too. I've only met a couple of airport cats, but I've lost count of the number of airport dogs who offered a welcome waggin' to itinerant pilots.

> **Many educational and proficiency benefits accrue from flying to unfamiliar airports.**

Places

No two airports are truly the same. Larger airports with commercial service are an amazing and meticulously organized maze of pavement with multi-colored lights and signs. Smaller airports can have some of everything, which is why it pays to do some research before you launch. During the Virginia Aviation Ambassador trips, my flying companions and I experienced everything from bowl-like

runways with a noticeable dip to short mountain-top strips to ski-slope runways with unidirectional takeoff and landing requirements.

Airport amenities are a pleasure as well. Though few GA airports could compete with the range of merchandise in mall-like major airports, you will find a wide range of pilot shops and, better yet, aviation-themed restaurants that contribute to an airport's unique character. A few airports also host aviation history museums.

> **Airports are a great place for aviation enthusiasts to see a wide variety of aircraft types.**

Planes

For those who participate in the sport of plane-spotting, what better way to feed the habit than to visit new airports? Even without a museum on site, airports are a great place for aviation enthusiasts to see a wide variety of aircraft types. I've stumbled upon warbirds, an astonishing variety of experimental/amateur-built planes and, best of all, old friends. I was delighted, for instance, to see the C150 that my flying club once owned on the ramp at its new home base in Delaware. I've sighted several of the humble but beloved birds I flew in primary training days at airports around the mid-Atlantic. Also, since learning the significance of the late 1990s-vintage C172 Skyhawks with the "ES" tail number (see "*The Legacy of Echo Sierra*" in the January/February 2010 issue of *FAA Aviation News*: bit.ly/FAASB-Arc), I have enjoyed looking for them.

Practicing Scenario-Based Training

The bottom line: visiting airports offers aviation educational and enjoyment opportunities with the added benefit of supporting our country's general aviation (GA) airport infrastructure. If your state has a formal airport visitation program, sign up. You can also use aviation community programs (e.g., AOPA's Pilot Passport) to expand your horizons and engage in friendly competition with like-minded pilots.

If you are an instructor or flight school operator, an airport visitation program, whether formal or DIY, is a great way to put scenario-based training into practice. Those in states with an airport visitation program could enhance the training experience by using it for both dual and solo cross-country flights. It also offers an incentive for structured "post-graduate" flying, both for proficiency and for earning higher certificates and ratings. Your local GA airports will appreciate your support, and there is no limit to how much you can learn and enjoy in the process.

Susan K. Parson (susan.parson@faa.gov) is editor of *FAA Safety Briefing* and a Special Assistant in the FAA's Flight Standards Service. She is a general aviation pilot and flight instructor.

NEW WAYS TO PREFLIGHT YOUR DESTINATION

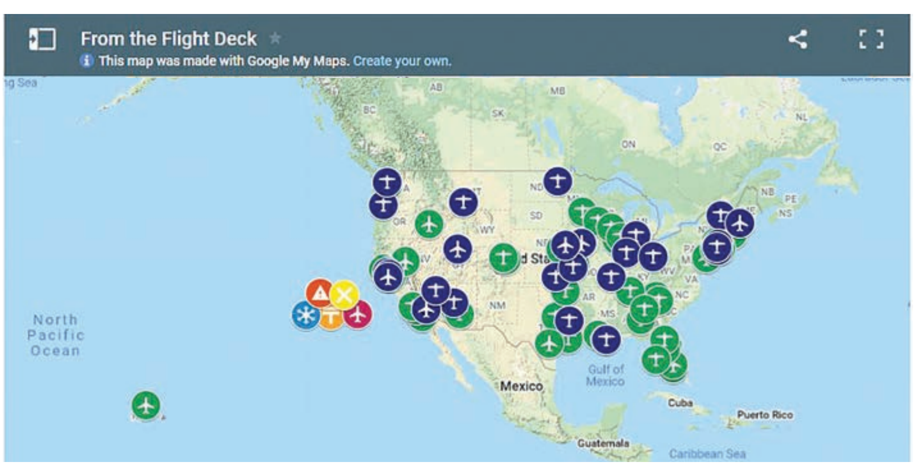
THE FAA'S *FROM THE FLIGHT DECK* VIDEO SERIES PROVIDES ACTUAL RUNWAY APPROACH AND AIRPORT TAXIWAY FOOTAGE, COMBINED WITH DIAGRAMS AND VISUAL GRAPHICS TO IDENTIFY SAFETY-SENSITIVE ITEMS.

We didn't have to use stone tablets and chisels when I was first learning to fly in the late 1990s, nor did I have to use hamster wheels or, worse, bicycle-style pedaling for propulsion. Even so, I sometimes feel like a fossil when I think about tools and techniques that now seem so quaint — even downright primitive. At the cross-country stage of training, for example, part of the drill was to get the flight school's dog-eared copy of the Airport/Facility Directory (now called the Chart Supplement) and look up the airport(s) to be visited on a dual or solo cross-country flight. Step two was to use paper and pencil to create a kneeboard-sized sketch of the runway configuration, using the edges to note things like frequencies and FBO information. Instructors also expected us to depict any obstacles on the approach path. I specifically remember that part because I had an ongoing informal competition with a fellow student whose hand-hacked airport diagrams were miniature works of art.

The work involved in creating these DIY airport sketches did have its benefits. Having to find, decipher, and depict safety-critical pieces of data helped embed this information more deeply in my sometimes-befuddled brain. Today, however, there are much better ways to make preflight visits through and to the airspace and airports that you intend to use. Even if you don't subscribe to any of the amazingly capable apps that abound these days, you can use Google Earth to skim over the terrain and explore your departure and destination airports. The app I use enables you to "pre-fly" a trip through the waypoints you load, and it offers three-dimensional airport depictions. Having been a map- and chart-geek for most of my life, I can happily spend hours using this online magic just to explore.

For the finishing touches, though, nothing beats seeing an actual flight to the place you plan to go. You can find plenty of such videos on YouTube, but the FAA has taken a more intentional approach through its growing series of From the Flight Deck videos (faa.gov/go/FromTheFlightDeck). This video series provides pilots with actual runway approach and airport taxiway footage captured with cockpit mounted cameras, combined with diagrams and visual graphics to clearly identify hot spots and other safety-sensitive items. The blue circles denote videos in development and clicking brings up a dialog box with the projected video release date.

Airports circled in green have a video already; just click on the circle for the name of the airport and a link to the actual video. The ones I've watched are around seven minutes long, but of course you can watch them as many times as you like. I especially like the way that the charted area appears in the upper left corner of the "real life" video footage, so you can simultaneously see both views and hear the explanation. It's a terrific, cost-free way to know before you go, so you can operate anywhere with competence and confidence.



An interactive map shows the locations of current (green) and future (blue) From the Flight Deck safety videos — faa.gov/go/FromTheFlightDeck.

Susan K. Parson (susan.parson@faa.gov) is editor of *FAA Safety Briefing* and a Special Assistant in the FAA's Flight Standards Service. She is a general aviation pilot and flight instructor.

LEARN MORE

From the Flight Deck
faa.gov/airports/runway_safety/videos

MISSION POSSIBLE

Advocating for GA in the TFR Process

By James Williams

Deep in the FAA sits an organization tasked with a mission. At first glance that mission might sound impossible. But the FAA's System Operations Security Directorate (SOS) is tasked with balancing the needs of various airspace users within the National Airspace System (NAS). SOS is your advocate for airspace restrictions and governs how they are made and implemented.

As you fly in the NAS, the common constraints you will encounter, often with limited notice, are Temporary Flight Restrictions (TFRs), especially those established by the FAA for security or emergency operations purposes. While TFRs, like most system constraints, are not exactly popular with pilots, it is important to understand that the FAA only uses this tool when needed to meet overriding requirements, including aviation safety demands. The agency consistently works to mitigate the impact of TFRs on pilots and the broader aviation community.

> **SOS is your advocate for airspace restrictions — how they are made and implemented.**

How the Airspace Gets Made

SOS is the primary FAA office responsible for air traffic management-related security and disaster response operations. As part of that mission, the SOS often acts as an intermediary between agencies responsible for national security and the general aviation community. Balancing the needs of airspace users, such as the Department of Defense and the Department of Homeland Security, with the need to maximize open access to publicly navigable airspace, is a critical consideration when SOS personnel evaluate TFR requests from these external agencies.

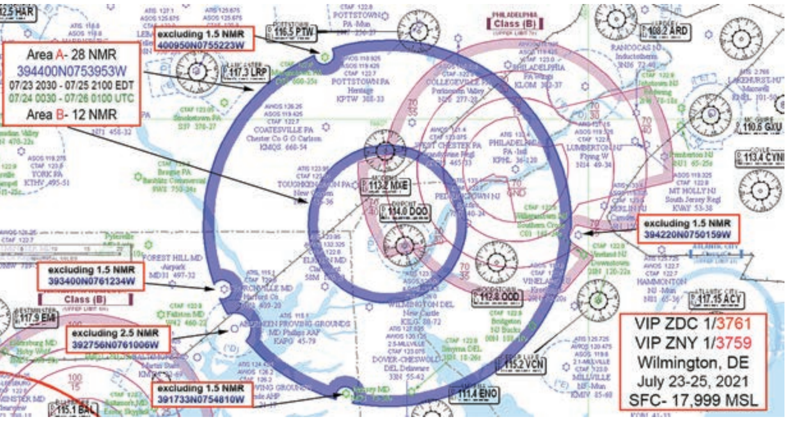
How SOS handles national security driven TFRs, including those implemented for presidential travel, provides a good look into the FAA's continuous work to ensure that TFRs are only used when really needed, and executed in a way that lessens their effect on operators and others in the aviation community.

SOS receives requests for security-related TFRs to cover parades, sporting events, large concerts, and other outdoor events on a regular basis. The FAA is required by law and regulation to establish national security TFRs in collaboration with the Department of Defense or other federal security and intelligence entities. SOS staff partner with representatives from all branches of the military and the federal law enforcement community to thoroughly address and vet each request that is received. All TFRs are designed and approved based upon a stringent evaluation by SOS and security partners, taking into consideration statutory and regulatory mandates, security risks, and impacts on the aviation community.

Everyone's NAS

One of SOS's core principles is to maximize free airspace access. This fundamental consideration is taken into account with every security TFR request. SOS routinely works with interagency partners to adjust TFRs as a means to ensure minimal impact to the aviation community. SOS staff works with the requesting agency to include only the essential needs for dates, times, and airspace. At times,

Photo courtesy of U.S. Air Force Senior Airman Taylor Crul.



interagency requests do not meet the defined, credible security threat criteria for issuing a given type of TFR. In these cases, SOS queries the requester. If credible threat information has not been received, the TFR is not approved. If there is a credible security threat, SOS issues a TFR and works with the requestor to determine a timeframe when normal airspace operations can safely and securely resume. While personnel from the Department of Defense, Department of Homeland Security, and the Department of Justice have significant input into vetting a TFR, the FAA retains the ultimate decision-making authority.

SOS is not limited to advocating on behalf of aircraft activity at large airports. In discussions with security partners, the FAA also advocates for other operations with a legitimate need to access airspace restricted by a TFR. For example, SOS may seek access for agricultural operations, community-based model aircraft organizations, or last-minute medical evacuation flights.

Maintaining the security of the NAS also requires notifying pilots of TFRs on a timely basis. Once a TFR has been published, SOS works very closely with pilot organizations to ensure the information is properly disseminated through a Notice to Airmen (NOTAM) and, in many cases, advisories distributed via the FAA's Safety Program Airmen Notification System (SPANS) to the widest audience possible (see www.faasafety.gov/spans to register or log in). "It is our intent to provide notification to pilots of flight restrictions well in advance to prevent any accidental incursions," says Gary Miller, the Director of SOS. "Such incursions require security partners to dedicate valuable time and resources to intercept unintentional TFR violators that could be used to mitigate a legitimate threat," he adds. As an added layer to increase public awareness, SOS routinely works with the FAA's Public Affairs office to communicate anticipated TFRs using the news media.

SOS routinely works with interagency partners to adjust TFRs as a means to ensure that a minimal amount of impact is felt by the aviation community.

SOS's mission isn't impossible but it is challenging. Many different stakeholders can have conflicting demands on the NAS. "Finding an appropriate balancing point that allows user access while protecting the security interests of our partners is not only SOS's challenge, but also its mission," says Miller. It's a mission they gladly accept.

James Williams is *FAA Safety Briefing's* associate editor and photo editor. He is also a pilot and ground instructor.

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Federal Aviation Administration

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AIRPORT GRANTS

1946-2021

How Federal Airport Grants Provide the Lifeblood for U.S. Airport Safety and Infrastructure

By Tom Hoffmann

With the stroke of a pen by President Harry S. Truman on May 13, 1946, the Federal Airport Act became law, establishing the first program to provide federal investment for airport infrastructure and development of the nation's civil airports. First up to receive a grant was Twin Falls, Idaho, where a new airport was constructed for about $647,000, of which $384,000 were federal funds. Over the following 75 years, the government has distributed $96 billion, (yes, with a "b") through grant programs to fund more than 82,300 airport projects. These grants have helped promote safety, security, efficiency, environmental stewardship, and infrastructure improvements at airports big and small across the nation.

Photo courtesy of the Magic Valley Regional Airport.

The Twin Falls Idaho Airport terminal building, circa 1948.

Background

Airport grant programs have existed in three forms, beginning in 1946 with the Federal-Aid Airport Program, then the more comprehensive Airport Development Aid Program in 1970, and most recently, the Airport Improvement Program (AIP), which was established in 1982. These programs evolved over time to keep up with the pace of the air travel industry and have expanded in both scope and size. For example, the AIP has been amended several times, most recently with the passage of the FAA Modernization and Reform Act of 2012. This update greatly increased the financial support for AIP grants and directed funds to be drawn from the Airport and Airway Trust fund, which is supported by user fees, fuel taxes, and other similar revenue sources. (For more details on the history of AIP, go to bit.ly/AIPHistory (PDF).)

"These grants represent the legacy and vital role of airport infrastructure grant programs in helping the air transportation system operate safely," said FAA Administrator Steve Dickson in an agency press release. "Investing in our nation's infrastructure through AIP grants is a cornerstone of our commitment to safety."

Project Management

That safety commitment is evident with the wide range of projects and enhancements AIP grants have covered over the years. Some of the more common requests include extend-

ing, repositioning, and/or rehabilitating runways, taxiways, and apron areas, installing airport surface lights and signage, and acquiring or upgrading emergency response equipment. However, AIP grants also cover a multitude of projects in some less obvious areas, like airfield drainage, erosion control, planning and environmental studies, airport access and service roads, perimeter fencing, obstruction hazard mitigation, snow removal equipment, and much more. At certain smaller airports, AIP grants may also be used to construct certain revenue-generating facilities like fuel farms or hangars to help airports be more self-sufficient. There are also options for projects that aid the environment, like zero or low-emission vehicles/equipment and charging stations, wildlife hazard assessments, geo-thermal heating and cooling systems, and solar power arrays (provided they meet strict requirements for any solar glare issues).

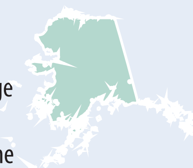
AIP funds can also be used for certain aircraft noise mitigation measures such as noise monitoring systems, compatibility studies, land acquisition, and noise mitigation testing and controls (e.g., insulation, window treatments) for homes, schools, and other buildings that fall within a certain day-night average sound level, or DNL. You can read more about DNL and the FAA's latest efforts to address aircraft noise in the Jul/Aug 2021 issue of this magazine.

Request to Build, Granted!

Here are some recent airport projects that have received AIP grants:

- **Frederick Municipal Airport in Frederick, Md. — Over $4.8 million** to extend Runway 05/23 to meet the operational needs of the airport. Additionally, this project relocates the parallel taxiway to meet federal design standards for separation between runways and taxiways.

- **Newtok Airport in Newtok, Alaska — Over $21.1 million** for construction of a new replacement airport in Newtok, Alaska. The project is critical to the airport and to the village of Newtok, which is home to an Alaska Native community of 374 residents. The airport and the community will relocate to higher ground due to erosion of the ground surrounding the airport and village.



- **Valdosta Regional, Valdosta, Ga. — Approximately $5.7 million** to rehabilitate 8,000 feet of Runway 17/35 maintaining the structural integrity of the pavement and minimizing foreign object debris. Additionally, this project enhances safety by removing vegetation obstructions from Runway 35's approach and departure paths.

- **Willow Run, Detroit, Mich. — Over $15.8 million** for shifting and reconfiguring the existing runway. This project will create jobs and continue to improve the safety and efficiency of the airport, which is important for cargo companies that support the auto industry.

Who's Eligible?

Heat map indicating AIP funding amounts by location (bit.ly/AIPfunding).

Now that we know a bit more about the types of projects that are eligible for AIP grants, it's time to look at whether your local airport is eligible to get its less-than-smooth runways repaved or maybe a new LED approach lighting system installed. Let's break it down.

The FAA works closely with more than 3,300 individual airports, related aviation organizations, and airport agencies to develop these critical airport infrastructure projects. To be AIP eligible, an airport must first be considered public-use, that is, an airport (including a heliport or seaplane base) that is open to the public *and* meets the following criteria:

- Publicly owned; or
- Privately owned but designated by the FAA as a reliever; or,
- Privately owned but having scheduled service and at least 2,500 annual enplanements.

AIP grant eligibility is also dependent on an airport being included in the National Plan of Integrated Airport Systems (NPIAS). The NPIAS, which is prepared and published every two years (bit.ly/NPIASairports), identifies public-use airports that are important to public transportation and contribute to the needs of civil aviation, national defense, and the postal service. In addition, an AIP grant recipient must be legally, financially, and otherwise able to carry out the assurances and obligations contained in the project application and grant agreement.

> **We're paving the way forward to a brighter future, one runway, taxiway, and airfield at a time.**

Don't Take It For Granted

Because the demand for AIP funds exceeds the availability, the FAA bases distribution of these funds on present national priorities and objectives. AIP funds are typically first apportioned into major entitlement categories such as primary, cargo, and general aviation. Remaining funds are allotted to a discretionary fund.

The FAA's Office of Airports (ARP) is responsible for administering the AIP, including ARP staff in FAA headquarters' regional offices, and district offices. The headquarters staff ensures that AIP administration follows the statutory requirements and oversees the effective use of AIP funds throughout the United States. The regional and district offices provide technical, financial, planning, environmental, and administrative support to NPIAS airports.

Projects identified to receive AIP funds are carefully scrutinized to ensure that they are eligible and justified for AIP participation based on their ability to enhance safety, improve security, satisfy aeronautical demand, and address environmental concerns. Projects are prioritized and must also meet selection criteria that is established by Congress and further refined in FAA policy.

This criteria also establishes how much of a project cost is covered. For large and medium primary hub airports, the grant covers 75 percent of eligible costs, while grants for small primary, reliever, and general aviation airports cover a range of 90-95% of eligible costs.

Grants To The Rescue!

To help support a network of more than 3,300 eligible airports, Congress allocates nearly $3.2 billion each year to AIP, along with approximately $1 billion in Supplemental Discretionary funding. Moreover, a series of additional economic relief programs were established to help airports contend with the COVID-19 public health emergency. They include the Coronavirus Aid, Relief, and Economic Security (CARES) Act, the Coronavirus Response and Relief Supplemental Appropriations (CRRSA) Act, and most recently, the Airports Rescue Plan Act of 2021 (ARPA). Together, these programs are providing nearly $20 billion in relief funding to airports affected by the pandemic. Also of note is the fact that both CARES and ARPA are providing funds at a 100% federal share, which allows critical safety and capacity projects to continue as planned regardless of an airport sponsors' current financial circumstances.

Under Obligation

When an airport receives federal assistance, the airport sponsor or owner must accept certain obligations and conditions that help ensure the safety and usability of their facilities. Some examples of obligations may include the proper maintenance and operation of airport facilities, the use of airport revenue, and protecting approach areas from development. The FAA encourages airport owners to review each agreement and conveyance document to ensure that they understand their obligations. These obligations help protect the federal government's investments in local transportation infrastructure and are a major reason why we have such a robust network of airports across the country.

75 Years and Counting

"Airports are powerful engines of economic growth and possibilities for local communities across the United States, and support millions of jobs," said FAA Deputy Associate Administrator for Airports Winsome Lenfert in a recent video message. She added that for the last 75 years, grants have allowed airports across the country to receive funding for forward-looking infrastructure investments and safety projects that have "yielded the safest and most efficient air transportation system in the world." Also important is the ability for these investments to promote environmental sustainability and improve access to diverse communities that depend on airports for transportation as well as receiving goods and services.

We're paving the way forward to a brighter future, one runway, taxiway, and airfield at a time.

Tom Hoffmann is the managing editor of *FAA Safety Briefing*. He is a commercial pilot and holds an A&P certificate.

LEARN MORE

AIP Overview page
faa.gov/airports/aip/overview

AIP 2021 Grant Map
faa.gov/airports/aip/2021_aip_grants/map

Annual AIP Report of Accomplishments and Grant Histories
faa.gov/airports/aip/grant_histories

Contact Info for FAA Airport Regional Offices
faa.gov/airports/news_information/contact_info/regional

Airport Rescue Grants Video
youtu.be/FNyruVDjnR4

Making It Count

How Aircraft Transponder Signals Take the Guesswork Out of Counting Non-Towered Airport Operations

By Jennifer Caron

"Many of the things you can count, don't count. Many of the things you can't count, really count."

— Albert Einstein

"I always feel like the runway is *just* long enough to keep me alive," one pilot comments on Reddit. Small taxiways, rough, bumpy runways, and insufficient signage are some of the frustrations pilots have expressed over the less than ideal conditions they've encountered, and would like to see improved, at some of the nation's general aviation (GA) airports.

When it comes to a funding decision on airport investments, there are many elements involved. According to the National Plan of Integrated Airport Systems (NPIAS), airport capital development needs are driven by current and forecasted traffic, use and age of facilities, and changing aircraft technology, to name a few.

But one important part of the decision puzzle is the total number of aircraft operations that happen at the airport. Aircraft operations counts are a key element in the overall criteria used to inform decisions on aviation systems and airport master planning, particularly for environmental studies and aviation forecasts, as well as airport design and funding. To borrow from Einstein's quote above, *Accuracy Really Counts*! Accurate and complete numbers inform the decisions that will rehabilitate those runways and taxiways, add that airfield signage, and smooth out that rough and bumpy surface.

So what are aircraft operations counts, and who's doing the counting?

The ATCs of 1-2-3s

Aircraft operations are defined in Title 14 Code of Federal Regulations (14 CFR) section 170.3 as the airborne movement of aircraft in controlled or non-controlled airport terminal areas. There are two types of operations: local and itinerant. Local operations are aircraft in the local traffic pattern, or in local practice areas, either within sight or at a 20-mile radius of the airport, and that includes touch-and-go landings. Itinerant operations take into account all the other non-local operations.

At airports with air traffic control (ATC), controllers track and record aircraft activity. With dedicated processes and personnel in place to count aircraft operations, it's more likely that the data collected is both accurate and complete. However, the vast majority of airports in the U.S. do not have ATC personnel to count aircraft activity. So who's counting the aircraft at those small, non-towered GA airfields, which often lack an on-site manager or fixed-base operator to take the count?

> **Current counting methods for non-towered airports varies in both accuracy and reliability.**

Let Me Count the Ways

When I first learned that aircraft operations counts take place at non-towered airports, I immediately pictured some random guy sitting just off the flight line in a green lawn

Pole-mounted Version II device installed at Terre Haute Regional Airport (KHUF) for data collection at a towered airport.

Stand-alone Version II device installed at Indianapolis Executive Airport (KTYQ) for data collection at a non-towered airport.

chair, binoculars slung around his sunburned neck, punching a hand-held counter for every takeoff and landing he could see. Obviously, that's not really how it's done, but that image is not too far off the mark.

Current counting methods for airports without ATC varies in both accuracy and reliability. The number and type of operations is often determined by the "best guess" of the airport manager, or based on prior-year counts estimated to the current date. The data is not standardized and the results are hodgepodge at best, making it difficult to compare data from one airport to another or to use the counts for high-confidence decision making.

Insufficient knowledge about aircraft activity at non-towered airports continues to be a concern for aviation agencies at both state and federal levels. A study by the Airport Cooperative Research Program found that many state aviation agencies, and some airports and planning organizations, have developed aircraft traffic counting programs to track airport activity, but with mixed results.

The FAA provides guidance on documenting aeronautical activity, including the number of operations by aircraft, in Advisory Circular 150/5000-17, *Critical Aircraft and Regular Use Determination*. Sources include aircraft landing fee reports, reliable aircraft logs recording aircraft make and model, data from commercial flight trackers, and completed instrument flight rules (IFR) flight plan data entered in the FAA's Traffic Flow Management System Counts (TFMSC) database.

"I can't say there's one predominant way airports do their traffic counts," says Michael Lawrance, Senior Aviation Planning Specialist in the FAA's Airports Planning and Environmental Division. "The use of TFMSC is a usual go-to source, but that only gets you aircraft that flew to your airport IFR, which typically accounts for about 25% of total operations." Kent Duffy, FAA Operations Research Analyst notes that "the TFMSC data is often sufficient to understand the need for a longer runway since the majority of business jets and large turboprops fly under IFR the majority of the time. However, the total operations data is still needed for aviation forecasts and the environmental studies needed to extend a runway."

Other methods include counting traffic year-round, sampling traffic seasonally to estimate annual operations, multiplying a pre-determined number of operations per based aircraft by the total aircraft based at the airport, performing regression analysis, and asking the airport manager — often the most used, and least accurate way to collect traffic counts. So can you picture the guy in the lawn chair now?

"Some airports supplement their data with fuel sales logs, FBO records, flight school activity, 'conversations with the airport manager,' or comparisons of other airports in the region," Lawrance explains. Other methods such as automatic acoustic counters, video devices, and pneumatic counters are not long-term solutions due to their expense and the impracticality of deploying these devices on a large scale. However, beyond the IFR data captured by TFMSC, many of these methods vary in both reliability and accuracy, resulting in low-confidence data.

"While many of those methods are fine for local planning purposes, they are not accurate enough for us to use in project justifications, primarily capacity-related projects," Lawrance explains. Relevant capacity projects that necessitate accurate total operations counts include new Federal Contract Towers or secondary runways to reduce congestion.

You Can Count On It

Research and innovation answers the call. PEGASAS looked at using signal strength obtained from aircraft transponders to accurately register operations counts. This technique is both innovative and economical, since it would re-purpose shelf-stable technology to address the need.

In 2016, Purdue University developed a transponder signal-counting technology to register operations with extended Mode S aircraft transponder signals. These signals are received with a 1090 MHz software-defined radio platform and contain global positioning system (GPS)-derived aircraft position information.

Mode S data captured includes unique ID, GPS latitude and longitude, elevation, and signal strength. This data is used to calibrate a model that has altitude and signal strength as inputs to estimate arrival and departure operations.

In 2017, the FAA tasked Purdue University under PEGASAS, the Partnership to Enhance General Aviation Safety, Accessibility, and Sustainability, an FAA Center of Excellence with a national network of researchers, educators, and industry leaders, to further evaluate an accurate, cost-effective means of conducting operations counts at non-towered airports using Mode S. The collaborative FAA/PEGASAS research team includes Jonathan Torres in the FAA's Airport Safety Technology Research and Development division at the William J. Hughes Technical Center, and university leads Darcy Bullock and John Mott at Purdue University.

The FAA required that most domestic aircraft operating in rule airspace be equipped with either Mode S, 1090 Extended Squitter, or Universal Access Transceiver (UAT) ADS-B transponders by January 1, 2020. The majority of GA aircraft are now equipped with ADS-B. However, there is a substantive share of GA aircraft that don't operate in rule airspace that still have only Mode C transponders. Not a problem since this novel, data-capturing technology uses an inexpensive ground-based radio receiver to monitor both Mode S and Mode C data and can easily obtain signals in a passive manner with no adverse impacts on aircraft communication or sensitive equipment.

To test and validate the transponder signal concept, the PEGASAS research team developed two versions of a signal counting device that monitors aircraft transponder data to count aircraft operations. Devices were deployed at four GA airports in Indiana, two towered and two non-towered. Version I devices (an experimental transponder signal receiver and processing system) were installed at the two towered airports: Purdue University Airport (KLAF), and Terre Haute Regional Airport (KHUF). Version II devices (a pre-production prototype of the transponder signal-counting technology) were installed at both towered airports and at two non-towered airports: Indianapolis Executive Airport (KTYQ), and Warsaw Municipal Airport (KASW).

These devices collected over 150 million transponder records to produce regular operations counts over different time periods, from 8 to 180 days. The operations counts calculated from these records were compared with those obtained from the FAA Air Traffic Activity Data System (ATADS) database, which contains official operations data reported by air traffic control towers at airports.

The accuracy of operations counts from the Version I devices ranged from -10.2% to 7.6%, as compared to the ATADS counts. The differences between ATADS and estimated operations counts from Version II ranged from -3.1% to 3.0%. The test results suggest that the new method of counting operations counts based on transponder signal data is more accurate than most of the other methods currently in use at non-towered airports. Overall test results indicate that the transponder signal-counting technology is an accurate and cost-effective way to count non-towered airport operations.

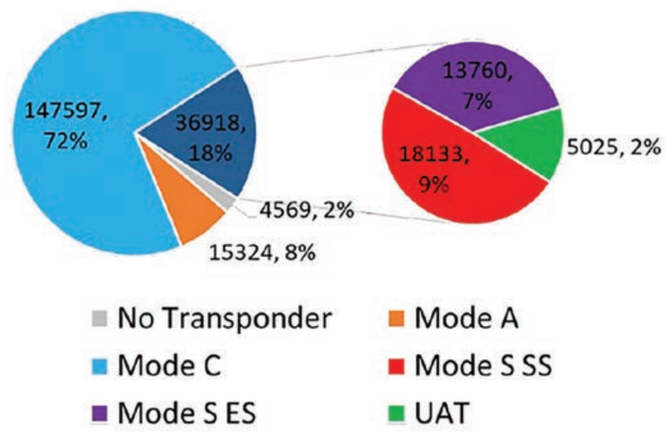


Image courtesy of PEGASAS.

The majority of GA aircraft are now equipped with ADS-B. However, there is a substantive share of GA aircraft that don't operate in rule airspace that still have only Mode C transponders. This project uses an inexpensive ground-based radio receiver to monitor both Mode S and Mode C data.

The Final Countdown

It's a winning concept, and generates cost-effective, accurate, and detailed operations counts. A transportation data services company called Quality Counts has already bought the license for this novel technology and has a product.

Looking ahead, the data collection continues. Further research involves refining the overall process to ensure the greatest possible accuracy in the count registration, including a means to gather more data, such as aircraft type. This information can provide additional insight to airport managers about the fleet mix of aircraft operating at their airports.

Set your clocks and stay tuned for updates on this exciting new technology.

Jennifer Caron is *FAA Safety Briefing*'s copy editor and quality assurance lead. She is a certified technical writer-editor in the FAA's Flight Standards Service.

LEARN MORE

See Here to Learn More About PEGASAS
bit.ly/FAASB-Arc — *FAA Safety Briefing* — **May/Jun 2018**

COMING SOON: MORE AIRSPACE FOR DRONE OPERATIONS

Drone pilots will have even more options than before when they seek permission to fly in controlled airspace this fall. The Low Altitude Authorization and Notification Capability, or LAANC, is getting a big enhancement that will enable drone pilots to operate in even more low-level airspace than before — and to know that they're doing it safely.

> **THIS FALL, DRONE PILOTS WILL HAVE EVEN MORE OPTIONS THAN BEFORE WHEN THEY SEEK PERMISSION TO FLY IN CONTROLLED AIRSPACE.**

Currently, the FAA divides the airspace around nearly 750 Class B, C, D, and E airports into grids that are each about one square mile. Each grid cell has a maximum safe UAS (unmanned aircraft system, or drone) operating altitude, on which FAA air traffic facility staff, controllers, and managers collaborate to determine. This is the highest altitude that is deemed safe for UAS to operate within each cell with an automatic approval through LAANC. These altitudes can range from zero (no flights allowed without further coordination, such as in areas above and immediately adjacent to airports) to 400 feet above ground level (AGL). The grouping of these grid cells comprises the UAS Facility Map, or UASFM, for a volume of controlled airspace. "The FAA is calling the enhancement 'Quad Grid,' explains LAANC Project Lead, Victoria Gallagher.

At present, drone operations can't be automatically authorized in some cells away from airports, especially

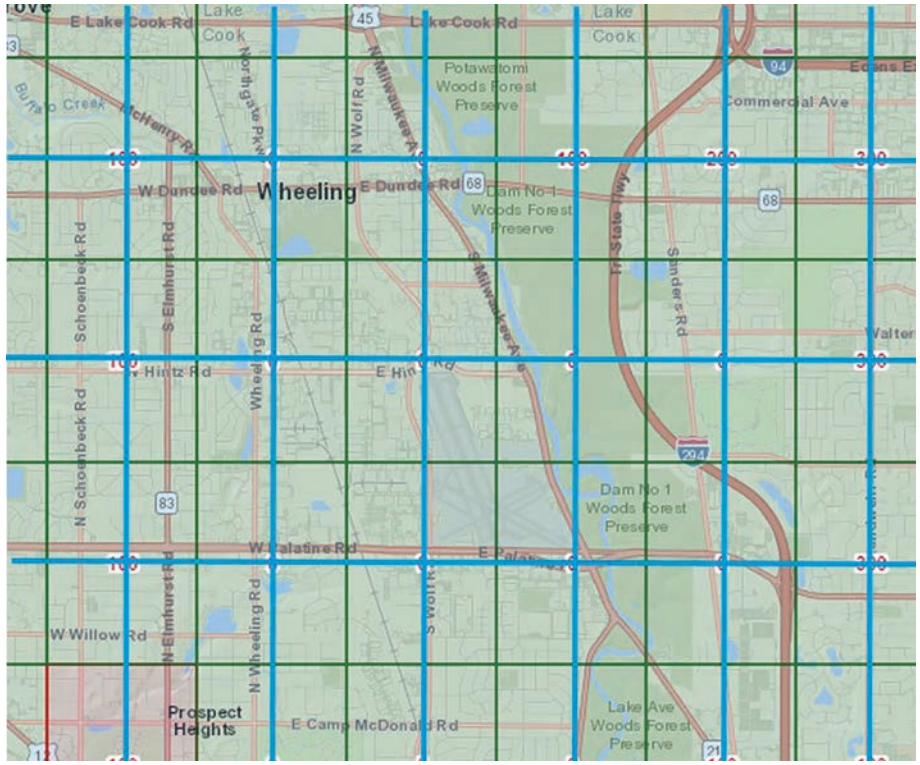


Figure 1: Current one square mile UAS Facility Map cells around Chicago Executive Airport (KPWK) are shown in green. With Quad Grids, represented by the additional blue lines, cells will be much smaller than before.

where hospital heliports are located, or where approach and departure paths clip one corner of a cell. That effectively locks out drone pilots from an entire square mile, when generally only a smaller area needs to be protected for crewed flights.

Once Quad Grids go into effect in the fall of 2021, each of those previous grid cells will be split into fourths, making the new Quad Grid cells about ½-mile on each edge. This holds the potential to safely open up airspace for drone operations in hundreds of locations across the United States by allowing UAS flights in some of the newly subdivided cells.

Because each LAANC UAS Service Supplier (USS) visualizes airspace differently, UAS pilots may not immediately recognize the four-fold increase in the number of UASFM grid cells, but under the hood, that's what will drive the difference in how airspace authorizations appear.

Since its inception in 2017, the LAANC system has worked well for the FAA and many commercial drone pilots who operate under part 107, as well as recreational pilots flying under Title 49 of the U.S. Code, Section 44809. In fact, the FAA's approved LAANC service providers have now processed more than 700,000 authorizations, the vast majority of which happen automatically and in a matter of seconds. But UAS operators have been asking for more flexibility, and that's where Quad Grids come in. "A square cell that is a mile on each edge doesn't naturally fit well with airspace boundaries, which are often circular," Gallagher notes.

The Quad Grid upgrade also gives air traffic control facilities more flexibility and precision when determining the maximum altitudes to set for each UASFM cell in their airspace. The current grid works well for airports with east-west and north-south runways, but facilities must be overly conservative to protect airspace underneath the approach and departure paths for diagonal runways. Once the new Quad Grids go into effect, facilities will have the option to be a bit more precise, based on their local traffic patterns. This could mean allowing UAS operations at 50 or 100 feet AGL, for example, adjacent to approach paths, if the facility determines doing so is safe.

"This has the potential to open up literally hundreds of square miles of airspace to drone pilots across the National Airspace System (NAS), without impacting the safety of operations for crewed aircraft," says Gallagher. Drone pilots would still be required to follow all other FAA regulations, such as registering their aircraft, flying within visual line of sight, and giving way to crewed aircraft.

Quad Grids are just one of many initiatives underway in the FAA to enable the safe integration of UAS into the NAS. Earlier this year, new rules went into effect that are making it easier for qualified UAS pilots to safely fly at night, or over people. The FAA has also started an Aviation Rulemaking Committee (ARC) focused on beyond visual line of sight operations. The ARC comprises about 90 representatives from across industry, local governments, tribal bodies, and others that will recommend changes to FAA rules and regulations with an eye toward further enabling the safe integration of advanced UAS operations.

The FAA is also looking at how to leverage its years of historical surveillance data to analyze airspace usage by crewed aircraft. Visualizations could help identify areas of uncontrolled airspace with frequent crewed aircraft activities, where UAS pilots would continue to need additional collision avoidance mitigation measures. The initatives could also help in identifying times of day when crewed aircraft operations are less likely to occur. That opens the door to exciting new possibilities of dynamic airspace management, by enabling futher UAS access in complex airspace, without limiting general aviation operations or increasing collision risk.

Peter Sachs is a UTM implementation program manager in the FAA's UAS Integration Office and previously worked as an air traffic controller at San Francisco Tower (KSFO) and Chicago Executive Tower (KPWK).

Figure 2: Consider the Class D airspace near Chico, CA. The UASFM altitude limit in two grid cells in the southern edge of this airspace is zero due to a hospital that falls within both grids. Following the transition to Quad Grids, many of the resulting eight cells will have a much higher altitude limit. Therefore, more of the Class D airspace would be available for automatic approvals. The FAA has planned an assessment to collect metrics and assess benefits in areas such as this one following the transition to Quad Grids.

Figure 3: Current UASFM assignments around Beverly Regional Airport (KBVY). The final approach for Runway 16, depicted with the pink arrow, clips the corner of one cell with a "0," indicating no automatic approvals. With Quad Grids, each facility would have the option to adjust altitudes in new, smaller cells (for example, the one shaded purple) that are farther from high-traffic areas.

JIM KENNEY, PAUL VONHOENE, and MATT HASKIN

ADS-B ON NON-ELECTRIC AIRCRAFT? WE ANSWER YOUR TOP QUESTIONS

The FAA frequently receives questions from pilots and aircraft owners who are curious about ADS-B Out installs on non-electric aircraft, including balloons, gliders, and ultralights. Here are your top questions and answers.

1. My aircraft has a battery to power the radio and transponder. Is that considered an electrical system? *No.*

The requirement to install ADS-B Out applies to aircraft certified with an engine-driven electrical system, or one that has it subsequently installed. Simply having batteries or an electric starter would not mean that your aircraft has an electrical system; therefore, it is not required to have ADS-B Out. For example, if you have a generator or alternator attached to the engine to charge a battery, then you have an engine-driven electrical system. If you just have a battery or an electric starter, then you don't.

***But what if my aircraft is subsequently installed with a battery?* The answer here is also *No.* See AC 90-114B, Section 3.2 (a link is in Learn More).**

2. My aircraft has a battery which means I am not required to equip with ADS-B Out, so does that mean I can fly in any airspace I want? *No.*

You must remain (1) Outside any Class B or Class C airspace area; and (2) Below the altitude of the ceiling of a Class B or Class C airspace area designated for an airport, or 10,000 feet mean sea level (MSL), whichever is lower. See "Do I Need to Equip" at bit.ly/WhoNeedsADSB, and 14 CFR 91.225 at bit.ly/equip2020 for more.

3. Can I install a battery-powered ADS-B Out system? *Yes.*

You can install a compliant, battery-powered ADS-B system, but it must be permanently installed. Portable ADS-B Out equipment (also known as "suitcase" units), including system components and antennas, do not comply. See AC 90-114B, Section 4.3.2 for more.

4. What if I have an experimental airworthiness certificate, do I have to install ADS-B Out? *No.*

The requirement to have ADS-B Out does not depend on the airworthiness certificate, but it does determine whether or not it needs to be certified. See bit.ly/ADSBOutInstalls (PDF). Aircraft with a type certificate require certified ADS-B equipment. Experimental aircraft may use non-certified ADS-B equipment. You can install equipment per manufacturer instructions.

5. What are the configuration requirements for the ADS-B Out system, and how do I know it's working?

Your avionics shop and manufacturer can help and advise you on available options and costs associated with any required upgrades. See AC 20-165B (a link is in Learn More). The best way to check your ADS-B is to run a Public ADS-B Performance Report (PAPR) report. It's online, free, with results in 15 minutes: bit.ly/PAPRequest.

6. I am not required to equip with ADS-B Out, but are there any benefits to installing a system anyway? *Yes.*

See and "B" Seen. ADS-B Out allows other aircraft who have ADS-B In, including those with collision avoidance systems, to see and avoid you, significantly reducing the risk of mid-air collisions. Your chances of a successful search and rescue mission also increases. You are also visible to UAS (drones) operating above 400 feet above ground level.

Situational Awareness. Equipping with both ADS-B Out and ADS-B In gives you traffic information (TIS-B), and flight information (FIS-B), and with 978MHz you get subscription free weather and text-based advisories such as NOTAMs and TFRs. *ADS-B In is not required.*

Jim Kenney and Paul VonHoene are aviation safety inspectors in the FAA's Flight Standards Flight Operations Branch. Matt Haskin is an aerospace engineer in Aircraft Information Systems at the FAA.

LEARN MORE

AC 90-114B, *Automatic Dependent Surveillance-Broadcast Operations*
bit.ly/ADSBOps (PDF)

AC 20-165B, *Airworthiness Approval of ADS-B Out Systems*
bit.ly/ADSBOutAirworthy (PDF)

AVOIDING THE HOTTEST "HOT SPOTS"

You've completed a challenging flight, maybe one that involves some bad weather. The approach was a success. The landing was among your best. But those visions of a perfect flight went up in smoke when you blundered into a runway "hot spot," which is what the FAA calls areas that carry an increased risk of runway incursions. Hot spots may include the intersection of two runways, the intersection of a runway and a taxiway, or parallel runways/taxiways that could lead to a wrong surface event.

Exploring Real "Hot Spots"

A good example of an airport that presents multiple challenges for surface operations is Flying Cloud Airport (KFCM) in Minneapolis. FCM has six identified hot spots where pilots can get disoriented at night or with low visibility. Two of these caution pilots about the potential for confusing the closely positioned Runways 28L/28R and 10L/10R on approach. The other four indicate areas on the ramp and taxiways that are in precariously close proximity to Runway 28R/10L.

Runway safety risks aren't limited to large-scale, multi-runway airports. They also exist at smaller, single-runway landing fields. At Houston's Sugar Land Regional Airport (KSGR) for example, you'll find a hot spot at the intersection of Taxiway E and Taxiways A and A3 where the short distance from Runway 17/35 increases the likelihood of conflict between aircraft.

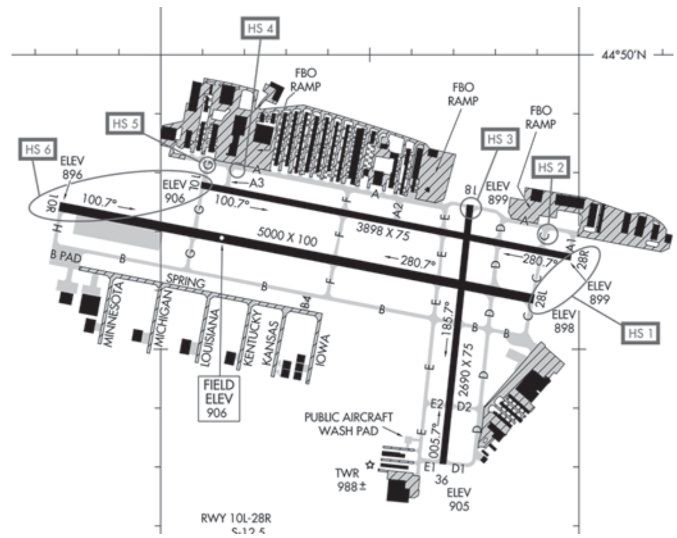
Bottom line: always review the airport chart and hot spot information before taxiing for departure and before landing. Both of these resources can be found here: bit.ly/RunwaySafetyDiagrams.

Don't Get Burned

Here are some self-briefing questions that will help you avoid being scalded by contact with a runway hot spot:

- What taxiways will I be using?
- Will I be crossing any runways?
- Are there any tricky intersections I should know about?
- Are there any known areas of confusion I should know about?
- Could weather or low lighting be a factor in maintaining awareness of my location?

To answer these questions, use all available tools to plan your taxi route. These include Automated Terminal Information Service (ATIS), Notices to Airmen (NOTAM), and the FAA's From the Flight Deck video series (faa.gov/go/FromTheFlightDeck) which provides helpful flight deck views of hot spot areas at more than 50 airport locations. It's a good idea to be on the lookout for airport construction notices too. Recent increases in federal assistance for airports mean increased likelihood of projects that could temporarily close taxiways, runways, or parking areas and cause you to alter your normal routing. You can see the list of airport construction notices here: bit.ly/ArptConstNotice. Most electronic flight bag apps offer these notices in a list or integrate them into a moving-map display. The FAA also has a short demo video outlining steps needed to view construction notice diagrams for a given airport (youtu.be/a91Q-XKA-tA).



Flying Cloud Airport has six identified hot spots.

If you become disoriented or unsure of your position while taxiing, make sure you are clear of any runway and stop. Advise ATC and, if necessary, request progressive taxi instructions. Don't be afraid to ask for help, and don't be afraid of saying "unable" when you are not ready or able to accept an ATC clearance. A recently added animation on the FAA's Runway Safety Simulator (runwaysafetysimulator.com) showcases a scenario where saying "unable" could have prevented a wrong-direction departure.

Remember that every airport is unique and presents its own set of runway safety challenges. So stay alert and stay alive!

Tom Hoffmann is the managing editor of *FAA Safety Briefing* magazine. He is a commercial pilot and holds an Airframe and Powerplant mechanic certificate.

LEARN MORE

Runway Safety Town Hall, June 16, 2021
youtu.be/wpLPTZsijfk

NEW GUIDELINES FOR HELIPORT PLANNING, DESIGN, AND CONSTRUCTION

Pilots, mechanics, and owners and operators of helicopter infrastructures — heliports and helistops — may want to be on the lookout in December for a revised FAA Advisory Circular (AC) that outlines recommended standards and guidelines for the planning, design, and construction of helicopter infrastructure.

This development comes at a time when helicopter infrastructure (heliports) and vertiports — landing spaces for vertical takeoff and landing (VTOL) aircraft — may increase in numbers, traffic volume, and importance nationwide as people and businesses look for faster and more efficient ways to get around.

HELIPORTS THAT FOLLOWED FAA GUIDELINES HAD SIGNIFICANTLY FEWER ACCIDENTS THAN THOSE THAT DID NOT.

Many ideas have emerged in recent years where helicopters can take passengers from downtown New York City to area airports. Other ideas would call for all-electric or hybrid-electric lithium battery or hydrogen-fuel-cell-powered VTOL that can serve as urban air taxis or alternatives to more traditional transportation options.

Historically, the FAA has taken an advisory role when it comes to standards for private-use heliports, which make up the vast majority of heliports. A similar advisory approach is expected for vertiports.

On December 16, 2020, the FAA Office of Airport Safety and Standards released a draft update to the Heliport Design Advisory Circular (AC) for industry comment. The AC outlines recommended standards and guidelines for the planning, design, and construction of heliports. According to the FAA Airport Design and Construction Branch, the final updated AC is expected later this year. An AC for vertiport design is under consideration while an interim vertiport design engineering brief is under development.

The final Heliport Design AC, to be released by the FAA Office of Airport Safety and Standards, provides recommended standards "for establishing an acceptable level of safety, performance, and operation for heliports." It also is intended to "assist engineers, architects, and city planners to design, locate, and build a suitable heliport." The sweeping document covers everything from the design elements that make up a heliport to structural and safety recommendations.

Researchers from the FAA Technical Center, in collaboration with other researchers from industry stakeholders, published a white paper in May finding that heliports that followed FAA guidelines had significantly fewer accidents than those that did not.

The researchers looked at 185 helicopter infrastructure accidents from 1965 through 2013, and discovered that 166 accidents (about 90%) could be attributed to improper infrastructure (airport, helideck, heliport, helistop) design and/or operations. In some cases, fences were too close and too high at take-off and landing areas, wires were installed near heliports without regard to their impact on the heliport's airspace, or the heliports were built in places that had "incompatible" airspace.

For several years, the FAA heliport design AC has stated that their design standards assume there will never be more than one helicopter within a heliport's final approach and takeoff area (FATO) and its associated safety area. However, the researchers found main rotor blade strikes between two helicopters either both turning, but more often one shut down and the other turning, or some area of the fuselage coming in contact with the main or tail rotor blades, usually involving parked helicopters or some other hazardous condition, according to one of the paper's authors from the FAA Technical Center.

The FAA is focused on continually improving design, construction, and operation guidelines for heliports and on educating pilots about heliport safety. The FAA's top priority is the safety of pilots and those who work with and around them.

Gene Trainor works as the communications specialist/executive technical editor for the FAA Compliance & Airworthiness Division.

Check out our GA Safety Facebook page at **Facebook.com/groups/GASafety**

If you're not a member, we encourage you to join the group of nearly 15,000 participants in the GA community who share safety principles and best practices, participate in positive and safe engagement with the FAA Safety Team (FAASTeam), and post relevant GA content that makes the National Airspace System safer.

From Our Twitter Channels — Stand By or Hold Short?

"Stand by" used to mean pilot or controller was too busy to answer, no response was expected or required. Now, tower controllers use it as shorthand for "hold short Rwy XX." A runway incursion waiting to happen. Plus, pilots are responding "Standing by," ... forehead slap.
— John

"Stand by" is an approved phraseology for Air Traffic Control (ATC) and pilots. It ***should never*** *be used by ATC as a replacement to hold short of a runway. It is simply a way of saying, "I will get back to you soon," or "I'm too busy to answer you right now, but I will be right back." "Stand by" should be treated the same as "Roger.*

Air Charter Chatter

Illegal air charter operations pose serious safety hazards. Can you spot an illegal air charter? Pop Quiz! Your team finally made it to the big game. You're a commercial pilot and you own a six-seater Piper Saratoga, so why not fly down with five of your closest friends to all enjoy the game live and in person. Question: Can you share the operating expenses for the flight? In our online poll, 83% said "Yes." Do you know the right answer?

To find out and learn more about air charter safety, watch this recorded webinar at bit.ly/FAAAirCharterWork shop, and check out the FAA's info page at: faa.gov/go/safeaircharter. Then test your knowledge at bit.ly/ALC-697, and you can earn Advanced WINGS credit!

Aircraft Mufflers — The Hidden Danger You Need to Know

I was flying eastward across the Appalachian mountains. The airplane was flying beautifully and all was well. By the time I got to the airport, I had a splitting headache. I was so exhausted that I just set the parking brake and slept in the airplane. I got out and slept in my car for another couple hours. The next day, I told a friend of mine who happened to be a volunteer EMT. He immediately recognized the symptoms as hypoxia. That's when the alarm bells went off. CHECK THE MUFFLER AND HEAT EXCHANGER. Sure enough, it was not in good shape. If I had not been in good physical shape at the time, I might not be here writing this.
— Jake

Hi Jake — Thank you for your email and for taking the time to share your experience. You make a great point about checking the muffler and heat exchanger. That's why we wanted to get the word out there to pilots and mechanics about the hidden dangers in the exhaust system at bit.ly/AircraftMufflers. Just taking a look inside can head off a potential incident or worse, a loss of life. It's a good thing that your EMT friend spotted the symptoms. We're very happy to hear that everything turned out ok!

What's The Buzz On Drones?

Take a look at the main points of the new Remote Identification and Operations Over People rules for drones at bit.ly/NewDroneRules.

For more stories and news, check out our new blog "Cleared for Takeoff" at medium.com/FAA.

Let us hear from you! Send your comments, suggestions, and questions to SafetyBriefing@faa.gov. You can also reach us on Twitter @FAASafetyBrief or on Facebook at facebook.com/FAA.

We may edit letters for style and/or length. Due to our publishing schedule, responses may not appear for several issues. While we do not print anonymous letters, we will withhold names or send personal replies upon request. If you have a concern with an immediate FAA operational issue, contact your local Flight Standards Office or air traffic facility.

SUSAN K. PARSON

NO PLACE LIKE 'DROME

"There's no place like home."

— Dorothy in the 1939 classic film, *The Wizard of Oz.*

Those who fly probably feel most at home in the sky, preferably in the pointy end of whatever plane we happen to occupy. But the aerodrome* might be a close second.

That is certainly true for me. My earliest memory is flying from Piedmont Triad International Airport (KGSO) in Greensboro to Newark Liberty International Airport (KEWR) on a B-727 "WhisperJet" when I was three years old. I loved the jet, but flying was a rare, special occasion mode of transportation in the mid-1960s. So, for many years the next best thing was Sunday afternoon visits to the airport. I'm not sure how my younger siblings felt — I never thought to inquire — but nothing was more exciting to me than hearing my parents announce a trip to GSO. Once there, we would make our way to the outdoor observation deck and watch the airliners come and go. Even then I was fascinated not only by the airplanes, but also by the well-organized and fast-paced ballet of the people who serviced arriving and departing aircraft.

In those early days of the Jet Age, the mere idea of airports easily conjured a magical mixture of adventure, possibility, and even romance. You'll find all three in Arthur Hailey's 1968 book, *Airport*, which I devoured in my youth. I own all the *Airport* movies inspired by that novel, and I occasionally treat myself to an airport movie marathon on Friday nights (*FWIW, the original still gets my vote for being the best of the bunch*). From time to time, I also reread the 1968 novel, if only to marvel at how much

TWA Hotel at New York's JFK Airport.

the aviation world has changed since then. Who today can imagine a commercial passenger service airport that doesn't require a security clearance?

If you share any of my fascination for — and appreciation of — the role that airports have played over the years, you might enjoy Alastair Gordon's quizzically-titled *Naked Airport: A Cultural History of the World's Most Revolutionary Structure*. First published in 2004, it opens with pictures and the story of a 1964 visit to New York's newly renamed John F. Kennedy airport: "the flashy stained-glass entry to American Airlines, the flying-saucer roof of Pan Am" and then the swoopingly modern "birdlike structure" of the TWA terminal. As you may know, the TWA terminal still exists as a boutique hotel offering a unique 1960s throwback experience. As the prologue to Gordon's book notes, "The airport is at once a place, a system, a cultural artifact that brings us face-to-face with the advantages as well as the frustrations of modernity. (…) Its history has been a recurrent cycle of anticipation and disappointment, success and failure, innovation and obsolescence. This book traces that history through mutations of technology, design, and marketing — showing how the airport was gradually shaped into a new kind of human environment."

From the largest air carrier mega-hub to the smallest GA aerodrome, each airport is a precious piece of our national aviation infrastructure. May we never fail to appreciate each one!

**As defined by the International Civil Aviation Organization (ICAO), an aerodrome is "a defined area on land or water (including any buildings, installations, and equipment) intended to be used either wholly or in part for the arrival, departure, and surface movement of aircraft." Though it is commonly and almost universally used in the United States, the term "airport" may imply a facility that has satisfied certain certification criteria or regulatory requirements. All airports are aerodromes, but not all aerodromes are airports.*

Susan K. Parson (susan.parson@faa.gov) is editor of *FAA Safety Briefing* and a Special Assistant in the FAA's Flight Standards Service. She is a general aviation pilot and flight instructor.

PETER SACHS

UTM Implementation Program Manager, FAA Unmanned Aircraft Systems Integration Office

Remember those little plastic headphones that connected to the armrest of an airliner? Peter Sachs does, because United Airlines' *Channel 9* sucked him into aviation while he tagged along on his dad's business trips.

"What a thrill!" he explained. "I learned to spot other aircraft out the window based on traffic calls, laugh at the jokes and ride reports, and keep track of our landing and takeoff sequence. At San Francisco International Airport (KSFO) — our home airport — I was in awe listening to controllers and pilots manage the mind bogglingly complex dance of big, loud jets. I tried to imagine myself doing it. A long and winding path eventually got me there."

Before becoming an air traffic controller in 2010, Peter earned private pilot and flight instructor certificates in college. An airline career wasn't of interest, so he opted for a "steady" career in print journalism. He reported from places like Cairo, Chicago, and Washington, D.C., but then the Great Recession hit.

"My first air traffic facility was Chicago Executive Tower (KPWK) — an ideal place for someone like me who thought himself a hotshot — to get put in his place trying to sequence business jets and *Skyhawks* or run simultaneous patterns on intersecting runways," he said. "I eventually got good at it, but not without a lot of go-arounds first."

Two years later, he got a call for duty at SFO, full circle to where his aviation journey began.

In 2013, Peter and his colleagues watched as Asiana Airlines Flight 214 cartwheeled down the runway and crashed. This tragic event motivated Peter to learn more about aviation safety. He got involved with the Standard Terminal Automation Replacement System (STARS) radar transition and electronic flight strips for controllers. In 2017 he was detailed to work quality assurance, identifying and fixing systemic safety problems at SFO.

But with a new son and no alternative to front-line shiftwork, Peter joined Airbus to work on Unmanned Aircraft System (UAS) Traffic Management (UTM). He leveraged his controller experience into UTM service architecture, applying safety culture concepts and contributing to development of UTM standards.

In 2020, Peter returned to the FAA to work on the strategic implementation of UTM. He works with a team that focuses on how to safely enable widespread and scalable deployment of complex UAS operations. A key challenge is determining effective ways to mitigate collision risk between UAS and traditional aircraft.

"The policies we put forward now, even for localized UAS operations, set a precedent, and we know that we need to ensure the safety of the NAS above all else," he explains. "Working through how to do that with technology, big data analytics, and applying the same layered mitigation strategies used for every VFR and IFR flight today is the challenge we greet every day."

Peter is also actively working to put "aviation safety culture" front and center for the drone community. He urges traditional pilots to take a drone pilot friend or colleague out flying to show them what it's like from a traditional cockpit — and then watch them fly their drone.

"This kind of cross-pollination and education within pilot communities can be a lot more effective at improving everyone's safety mindset than an FAA enforcement campaign."

Paul Cianciolo is an associate editor and the social media lead for *FAA Safety Briefing*. He is a U.S. Air Force veteran, and an auxiliary airman with Civil Air Patrol.

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Look Who's Reading FAA Safety Briefing

Air Show and Race Pilot Sean Tucker takes *FAA Safety Briefing for a "spin."*

faa.gov/news/safety_briefing

@FAASafetyBrief

ATTENTION : PROJET D'ÉOLIENNES GIGANTESQUES

(Parc d'éoliennes de La Roche-en-Ardenne sur la crête de Beausaint à Vecmont)

Accepter le parc éolien n'est pas une bonne action

La région de la Roche-en-Ardenne vit principalement du tourisme mais sa richesse NATURELLE sera moins attractive si elle est défigurée par un parc éolien industriel[2]. La chute des revenus du tourisme sera beaucoup plus importante que ce que les éoliennes pourraient rapporter à la Commune.

Le projet prévoit, entre autres, de mettre une éolienne de 150 m de haut (5 fois plus haute que le clocher) à 600 m du PICHE de Beausaint .

Des campagnes médiatiques font croire *« qu'accepter des éoliennes est une bonne action »*. Des promoteurs se présentent comme des idéalistes soucieux de l'environnement mais leur but final est de faire des profits en exploitant des parcs éoliens. L'histoire est pleine de gens qui profitent de bons sentiments pour faire adopter leurs buts intéressés. Pour vous convaincre, lisez : *« Éoliennes : la Grande Arnaque »* par C. Gerondeau (2008, disponible sur Internet[1]).

L'éolien qui semble gratuit est en fait le moyen le plus cher de produire de l'électricité à la demande. Ce paradoxe est expliqué sur notre site[2].

L'ÉOLIEN ARDENNAIS EST INEFFICACE

Les éoliennes en mer ont deux fois plus de vent qu'en Ardenne et les centrales à gaz, qui continuent à fournir de l'électricité quand le vent diminue, émettent deux fois moins de CO_2 que pour les éoliennes terrestres[2].

Des campagnes médiatiques font croire que les éoliennes profitent à l'environnement mais les éoliennes, quand il n'y a pas assez de vent, nous forcent à utiliser du gaz naturel, le combustible fossile le plus cher après le pétrole réservé aux transports. Notre pays sera ainsi sous la dépendance des quelques fournisseurs de gaz. Nous aurions alors la même insécurité d'approvisionnement énergétique que l'Ukraine et la Biélorussie qui ont subi des chantages à la coupure de gaz[2].

Les Ardennes produisent plus d'énergie renouvelable

EOLIENNES GIGANTESQUES

- 6 Éoliennes de 150 mètres de haut
- Pales de 100 m de diamètre
- Éolienne de 1000 tonnes sur une fondation bétonnée de plus de 1000 tonnes.

TROP PROCHES DES MAISONS (à 350 m)

- à 200 m de la ferme de M. Renard.
- Les petites éoliennes proposées auparavant ne pouvaient pas être placées à moins de 350 m des maisons. Les éoliennes prévues ont 150 m de haut, sont 50% plus puissantes et sont encore placées aussi près.

TROP DE BRUIT

Le promoteur Electrabel ne connaît pas encore les caractéristiques des éoliennes qu'il veut installer mais demande déjà un permis. Il demande donc un CHÈQUE EN BLANC. Les petites éoliennes font déjà **trop de bruit** la nuit (45 décibels alors que le bruit de fond nocturne dans la région est en dessous de 30 dB). De plus, le promoteur suppose que le bruit de machines 50% plus puissantes sera le même !

TROP DE PUISSANCE

- La puissance du projet est passée de 8 millions de watts pour un parc de 4 éoliennes en 2004 à 18 millions de watts en janvier 2008. Accepter le projet d'aujourd'hui conduira inévitablement à une forêt d'éoliennes plus tard !

TROP DE FEUX CLIGNOTANTS

- Puissants feux rouges à éclats toute la nuit
- Feux de jour en cas d'exercice militaire.

- TROP DE RISQUES D'IMPACT SUR LE TOURISME SUITE A LA PERTE DU CADRE NATUREL DE L'ARDENNE

- TROP D'EMPLOIS PERDUS DANS LE TOURISME

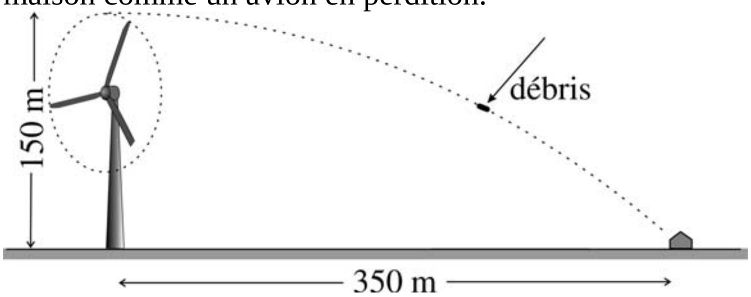
- CHUTE DES PRIX IMMOBILIERS (TERRAINS, MAISONS, GÎTES ...) ET DES INVESTISSEMENTS FUTURS

- ON A REFUSÉ LES ÉOLIENNES SUR LA CÔTE BELGE ! ON DOIT LES REFUSER AUSSI DANS LES STATIONS ARDENNAISES !

en exploitant leur bois que ce qu'ils pourraient générer avec 2000 éoliennes. Une bonne gestion est de s'occuper de ce que l'on fait bien, que ce soit du bois en Ardennes ou de l'éolien en mer à la Côte. Une mauvaise gestion consiste à détruire son capital touristique par de l'éolien. La nouvelle directive de la Commission européenne (janvier 2008) permet de comptabiliser le bois de chauffage comme énergie renouvelable en remplacement d'énergies servant à générer de l'électricité. La Wallonie peut ainsi satisfaire les demandes de réduction de CO_2 sans employer de l'éolien[2].

LE PROJET D'EOLIENNE EST DANGEREUX ET INUTILE

Electrabel compte installer un nouveau type d'éolienne qui n'existe pas encore et n'a donc pas été testé. Les éoliennes expérimentales ont souvent eu des ennuis (bruits d'origine inconnue, vibrations suivies de bris de pales). La forme des pales expérimentales est modifiée jusqu'à ce qu'elles ne vibrent plus dangereusement et que le bruit soit atténué. Les jours de tempête, les riverains devront dormir en craignant qu'un bout de pale brisée (plusieurs tonnes) soit projeté à 300 km/h (vitesse au bout des pales) sur leur maison comme un avion en perdition.



Destruction du paysage

- Il y a 455 riverains dans un rayon de 1 km des éoliennes. Ces riverains de Beausaint, Vecmont, Ronchamp et Ronchampay serviront donc de cobayes pour tester un nouveau type d'éoliennes.
- À Beausaint, une éolienne est à 600m et dans l'axe d'une zone PICHE *(Périmètre d'intérêt culturel, historique et esthétique)*. Les PICHEs de Hives et Lavaux seront dénaturés par la PRESENCE des éoliennes.
- Les éoliennes domineront le paysage depuis des routes et chemins ayant des *« Vues remarquables »* mentionnées sur les cartes officielles et attirant le tourisme (entre Halleux et Petit Halleux, à Cielle, Mierchamps, Lavaux et Journal).

À La Roche, la politique pour faire accepter les éoliennes a été de faire une enquête d'incidence discrète. En effet, ceux qui ne sont pas au courant des nuisances ne se plaignent pas et les protestations viennent trop tard. Notre site Internet est destiné à informer la habitants afin qu'ils puissent réagir en temps utile[2].

Coûts exorbitants répercutés sur le prix de l'électricité

- Il n'y aurait pas d'éoliennes si elles n'étaient pas fortement subsidiées.
- Un parc de 18 MW (6 éoliennes de 3 MW) produit 42 GWh par an (si le facteur de charge est 26% comme Electrabel le prétend). Pour cette puissance, le promoteur recevra des subsides pendant 15 ans dont le total s'élève à 44 millions d'euros[2].
- Le facteur de charge en Ardenne n'est probablement que de 16,5% (temps compté en équivalent pleine puissance)[2].
- Les subsides, équivalent à un accroissement de la dette nationale, seront remboursés par une augmentation correspondante du prix de l'électricité, c'est à dire, par nous et nos enfants.

COMMENT S'OPPOSER AU PARC EOLIEN

Ailleurs, des comités de riverains ont empêché des promoteurs de détruire leur environnement. La Roche-en-Ardenne, qui vit de son tourisme, est particulièrement menacée. Vous pouvez aussi vous opposer au projet en cours et protéger votre cadre de vie et celui de vos voisins.

Le dossier et la demande de permis peuvent être consultés au service urbanisme de la commune tous les jours ouvrables et le samedi matin. Si vous êtes d'accord avec quelques arguments cités ici ou sur notre site, vous pouvez réclamer dans le cadre de l'enquête publique jusqu'au **mercredi 20 février à 11 heure** en remettant une lettre (contre reçu) avec vos nom et adresse à l'**Administration communale de La Roche-en-Ardenne, Place du Marché 1, 6980, La Roche-en-Ardenne**, lettre (qui peut être collective) dans laquelle vous écrivez pourquoi vous vous opposez à ce permis, par exemple :

« Je m'oppose au projet de parc éolien parce que je crains que cela ne réduise le tourisme et donc l'emploi et le prix de l'immobilier. Je m'oppose aussi par solidarité avec ceux qui devront supporter des éoliennes gigantesques localisées à proximité de leur maison. »

Références

[1] C. Gerondeau, *Éoliennes, la Grande Arnaque*, http://www.environnementdurable.net/documents/html/gerondeau1.htm
[2] Des explications détaillées se trouvent sur notre site internet : http://www.leseoliennes.be/ : Les chiffres et résultats de calculs donnés ici (production, facteurs de charges, subsides, CO_2 évité, % renouvelable pour le bois) sont justifiés sur ce site.

Éditeur responsable : J. P. de Limbourg, Halleux 35, 6986, La Roche-en-Ardenne

What's New and Upcoming in Airman Testing

(New Edition: September 10, 2021)

Airman Knowledge Testing

New/Revised Test Question Activation Dates for 2021/2022:

- September 27, 2021
- January 31, 2022
- April 25, 2022
- July 25, 2022
- October 31, 2022

General Information:

New Knowledge Test Score Review (previously called "Hand-Score") and updated FAQs on FAA.gov:

FAQ Question:

What recourse do I have if I believe there was an invalid question on my airman knowledge test?

Answer:

The Airman Certificate Testing Service (ACTS) vendor's (PSI) software provides an opportunity for airman applicants to enter comments on each individual knowledge test question. Airman applicants should provide any comments, on knowledge test questions, during the test. Airman Testing Standards Subject Matter Experts regularly review these comments, determine any necessary action, and implement corrections and updates to test questions, as deemed appropriate.

*If you believe an invalid test question(s) contributed to your **failure** on an airman knowledge test, you may request a **Knowledge Test Score Review** (previously called "Hand-Score"), per the following instructions:*

Request for Knowledge Test Score Review: Airman Applicant Instructions

If your failed test meets the following criteria, you may request a knowledge test score review:

- ✓ *The date of your request, **and** the date of your failed Airman Knowledge Test Report (AKTR) are within the validity period stated on the report.*

Note: *Refer to the "Expiration Date," on your failed AKTR, in order to determine the validity period.*

- ✓ *Your failed knowledge test score is between 64 and 69, inclusive.*

Note: *The FAA will not review passed knowledge tests. Your passed AKTR should be presented to an authorized instructor, for additional instruction, and for confirmation of your competency in the subject area(s) missed on the knowledge test.*

If your failed test meets the above criteria, you may request a knowledge test score review by sending an email to afs630comments@faa.gov.

- ✓ *Your emailed request should include a:*
  - *written request stating the nature of your concerns;*
  - *legible photocopy of your proof of identification, including an official photograph of yourself;* ***and***
  - *copy of your failed AKTR.*

Your test results will be reviewed by an FAA airman knowledge subject matter expert. You should receive a response no later than 10 business days from the date your request was received.

Practice Tests and Sample Test Questions in PDF Format:

The PSI Practice Tests and FAA PDF Sample Questions on FAA.gov are updated as needed and do not wait for the change activation dates listed above. This What's New, PSI Practice Tests, and FAA PDF Sample Questions are used to communicate to the aviation community what has changed on the official FAA Knowledge Exams. The PSI Practice Tests and FAA Sample Questions have the same data, provided in different ways, and are an accurate reflection of the scope and depth of the FAA Knowledge Tests to support training and test preparation efforts. Applicants should reference the Airman Certification Standards to understand the expected knowledge and skills, and these airman knowledge testing tools to understand the computer testing process and example test questions.

PSI Practice exams are available via the PSI True Talent Website.

Sample Test Questions in PDF Format:

FAA PDF Sample test questions are available at
https://www.faa.gov/training_testing/testing/test_questions/

Changes to PLT Codes:

PLT codes added to the Learning Statement Reference Guide document:

- PLT550 Recall risk management – identification / assessment
- PLT551 Recall risk management – FRATs
- PLT552 Recall collision avoidance - TIS

The Learning Statement document is located here (dated 9-27-2021):
https://www.faa.gov/training_testing/testing/media/LearningStatementReferenceGuide.pdf

Several Tasks in the airplane question banks and associated knowledge test questions were reviewed for ACS code consistency and coding changes were made to questions to provide a more appropriate and consistent look-back for the applicant, instructor, and DPE depending on the question subject matter. Applicant practical exams will retest the ACS codes identified on the Airman Knowledge Test Report consistent with the code definitions in effect at the time of the test.

Private Pilot (PVT):

- We plan to add a code in the future when we can revise ACS for questions regarding the responsibility for airworthiness regarding pilots and owner/operators. Currently those questions are coded as PA.I.B.K1 (General airworthiness requirements and compliance for airplanes, including:)
- Questions about aircraft certification categories and classes with disparate codes were changed from PA.I.A.K2 (Privileges and limitations) to PA.I.B.K1 (General airworthiness requirements and compliance for airplanes, including) so questions on this topic have a consistent code.
- Alteration and repair questions that relate to required checks after alteration and return to service and other inspection such as annual inspection were changed from PA.I.B.K1 (General airworthiness requirements and compliance for airplanes, including) to PA.I.B.K1b (b. Required inspections and airplane logbook documentation).
- Questions involving minimum safe altitudes were changed from PA.I.D.K1 (Route planning, including consideration of different classes and special use airspace (SUA) and selection of appropriate and available navigation/com systems and facilities) to PA.I.D.K2 (Altitude selection accounting for terrain and obstacles, glide distance of the airplane, VFR cruising altitudes, and the effect of wind.)
- Questions about route selection not directly related to elements of a VFR flight plan were coded from PA.I.D.K4 (elements of a VFR flight plan) to PA.I.D.K1 (Route planning, including consideration of different classes and special use airspace (SUA) and selection of appropriate and available navigation/communication systems and facilities).
- Question codes were switched between PA.I.E.K1 (Types of airspace/airspace classes and associated requirements and limitations) and PA.I.E.K2 (Charting Symbology) depending on whether decoding a chart symbol or knowledge of airspace was the focus of the question.
- Some questions regarding standard classes of airspace designated by a single letter were changed from PA.I.E.K3 (Special use airspace (SUA), special flight rules areas (SFRA), temporary flight restrictions (TFR), and other airspace areas) to PA.I.E.K1 Types of airspace/airspace classes and associated requirements and limitations.
- Basic questions related to pilot analysis of effects of the density altitude on airplane performance were changed from PA.I.F.K1 (Elements related to performance and limitations by explaining the use of charts, tables, and data to determine performance) to PA.I.F.K2a (The applicant demonstrates understanding of: Factors affecting performance, to include: a. Atmospheric conditions.

Commercial Pilot (COM):

- Code changed to CA.I.G.K1i

  Your aircraft has an exhaust manifold type heating system. The exhaust manifold is periodically inspected to avoid

  Code changed from: The applicant demonstrates the ability to identify, assess and mitigate risks, encompassing failure to detect system malfunctions and failures.

  Code changed to: The applicant demonstrates the understanding of airplane systems, to include environmental.

The replacement code provides a more specific lookback to the system described in the question.

- A more specific code was applied to a question from general airworthiness requirements (CA.I.B.K1) to those requirements including certificate location and expiration dates (CA.I.B.K1a).
- A question regarding a chart symbol was changed from CA.I.E.K1 (Types of airspace/airspace classes and associated requirements and limitations) to CA.I.E.K2 (chart symbology).
- A question regarding load factor was changed from CA.I.F.K2e (Loading (e.g., center of gravity)) to CA.I.F.K3 (aerodynamics).
- A question regarding what the pilot does operationally as a result of a change in density altitude was coded from CA.I.F.K2a (a. atmospheric conditions) to CA.I.F.K1c (c. powerplant and propeller).
- A question about stress management was coded from CA.I.H.K1 (The symptoms (as applicable), recognition, causes, effects, and corrective actions associated with aeromedical and physiological issues, such as, to CA.I.H.K1g (The symptoms (as applicable), recognition, causes, effects, and corrective actions associated with aeromedical and physiological issues, such as, g. Stress).

Instrument Rating (IRA):

- A question about logging instrument approaches was changed from IR.I.C.K2 (Privileges and limitations) to IR.I.A.K1 (Certification requirements, recent flight experience, and recordkeeping.)
- A question about time and fuel burn was changed from IR.I.C.K1 (Route planning, including consideration of the available navigational facilities, special use airspace, preferred routes, and primary and alternate airports.) to IR.I.C.K3a (Calculating: a. Time, climb and descent rates, course, distance, heading, true airspeed, and groundspeed).
- For questions regarding specific data on an approach plate, the code was changed from IR.I.C.K1 (Route planning, including consideration of the available navigational facilities, special use airspace, preferred routes, and primary and alternate airports.) to IR.VI.E.K1 (Elements related to the pilot's responsibilities, and the environmental, operational, and meteorological factors that affect landing from a straight-in or circling approach.) or IR.VI.B.K1 (Procedures and limitations associated with a precision approach, including determining required descent rates and adjusting minimums in the case of inoperative equipment.) or IR.VI.C.K1 (Elements related to missed approach procedures and limitations associated with standard instrument approaches, including while using an FMS or autopilot, if equipped).
- Questions about weather products were changed from IR.I.C.K2 (Altitude selection accounting for terrain and obstacles, glide distance of airplane, IFR cruising altitudes, effect of wind, and oxygen requirements.) to IR.I.B.K2 (Acceptable weather products and resources utilized for preflight planning, current and forecast weather for departure and en route operations and arrival phases of flight.)
- A question about en route charts was changed from IR.I.C.K2 (Altitude selection accounting for terrain and obstacles, glide distance of airplane, IFR cruising altitudes, effect of wind, and oxygen requirements.) to IR.I.C.K1 (Route planning, including consideration of the

available navigational facilities, special use airspace, preferred routes, and alternate airports.)

- A question about filing a flight plan was changed from IR.I.C.K4 (Elements of an IFR flight plan.) to IR.III.A.K1 (Elements and procedures related to ATC clearances and pilot/controller responsibilities for departure, en route, and arrival phases of flight including clearance void times.)
- A question about clearance void times was changed from IR.I.CK5 (Procedures for activating and closing an IFR flight plan in controlled and uncontrolled airspace.) to IR.III.A.K1 (Elements and procedures related to ATC clearances and pilot/controller responsibilities for departure, en route, and arrival phases of flight including clearance void times.)
- A question about fuel requirements was changed from IR.I.C.R7 (Improper fuel planning.) to IR.I.C.K3c (c. Fuel requirements, to include reserve)

Airline Transport Pilot (ATP):

- A practice question stem now reads:
- In a turbojet aircraft, when is braking performance optimized during landing?
- "In a turbojet aircraft," was added to the stem since braking performance may include aerodynamic braking.
- Questions regarding the effect of high elevations, temperatures, and density altitude on takeoff was changed from AA.I.B.K2b (b. Takeoff performance (e.g., balance field length, VMCG) to AA.I.B.K3a (Factors affecting performance, to include: a. atmospheric conditions).
- A question involving reading available takeoff distance was changed from AA.I.B.K2b (b. Takeoff performance (e.g., balance field length, VMCG) to AA.I.B.K3d (Factors affecting performance, to include: d. Airport environment (e.g., runway condition, land and hold short operations (LAHSO))
- A question looking at a takeoff chart was coded from AA.I.B.K2c (c. Climb performance) to AA.I.B.K2b (b. Takeoff performance (e.g., balance field length, VMCG).
- A question not involving inoperative powerplant was changed from AA.I.B.K2g (g. Performance with an inoperative powerplant for all phases of flight (AMEL, AMES) to AA.I.B.K2b ((b. Takeoff performance (e.g., balance field length, VMCG).
- Questions about pallet weight and floor loads had inconsistent codes. Those coded to AA.I.B.K2h (h. Weight and balance and how to shift weight) were all coded to AA.I.B.K3e (e. Loading (e.g., center of gravity).
- Certain questions involving calculating weight and balance were changed from IAA.I.B.K3e (e. Loading (e.g., center of gravity) or from AA.I.B.K3f (Factors affecting performance to include: f. Aircraft weight and balance) to AA.I.B.K2h (h. Weight and balance and how to shift weight).
- Some questions coded with AA.I.B.K4 (Aerodynamics and how it relates to performance were changed to AA.I.B.K3e (Loading (e.g., center of gravity) or AA.I.B.K1 (Elements related to performance and limitations by explaining the use of charts, tables, and data to determine performance.) to better match what the question subject matter.
- Question relating stability and CG location was changed from AA.I.B.K5 (Adverse effects of exceeding an aircraft limitation or the aircraft operating envelope.) to AA.I.B.K5 (Factors affecting performance, to include: e. Loading (e.g., center of gravity)).

- Some questions coded AA.I.F.K3 (Aeronautical Decision-Making (ADM) using Crew Resource Management (CRM) or Single Pilot Resource Management (SRM), as appropriate.) were changed to AA.I.F.R2 (Hazardous Attitudes.) and vice versa as appropriate to the content of the questions.
- A question on automation coded with AA.I.F.R3 (Distractions, improper task management, loss of situational awareness, or disorientation.) was coded to AA.I.F.K4 (Aeronautical Decision-Making (ADM) using Crew Resource Management (CRM) or Single Pilot Resource Management (SRM), as appropriate.)

Airman Knowledge Test Reports:

Airman Certification Standards (ACS) codes will be printed on the Airman Knowledge Test Report (AKTR) for ACS-based exams. Currently, the following exams are based on published ACS documents: ACM, ASC, ATM, ATS, CAX, CCP, ICP, IEP, IFP, IRA, MCN, PAR, PCP, PEP and UAG.

- UGR is no longer administered
- IEP and PEP were added

Airman Knowledge Testing Matrix:

- The FAA Airman Knowledge Testing Matrix was effective April 6, 2021. The latest version is posted here.

Airman Knowledge Test Statistics:

Airman Certification calendar year 2020 statistical information is now available here.

Airman Certification Standards (ACS) New Development/Revision Update

ACSs under revision/development (release dates TBD):

- FAA-S-ACS-1, Aviation Mechanic General, Airframe, and Powerplant ACS
- FAA-S-ACS-2, Commercial Pilot Powered-Lift ACS
- FAA-S-ACS-3, Instrument Rating Powered-Lift ACS
- FAA-S-ACS-5, Airline Transport Pilot and Type Rating for Helicopter ACS
- FAA-S-ACS-9, Aviation Instructor ACS
- FAA-S-ACS-14, Instrument Rating – Helicopter ACS
- FAA-S-ACS-15, Private Pilot – Helicopter ACS
- FAA-S-ACS-16, Commercial Pilot – Helicopter ACS
- FAA-S-ACS-17, Airline Transport Pilot and Type Rating for Powered-Lift ACS
- FAA-S-ACS-18, Private Pilot Lighter-Than-Air ACS
- FAA-S-ACS-19, Commercial Pilot Lighter-Than-Air ACS

Testing Standard (TS) New Development Update

TS under development (release date TBD):

- FAA-S-TS-25, Inspection Authorization (IA) TS

Reference Handbooks New Development/Revision Update

With the assistance of aviation community members of the Aviation Rulemaking Advisory Committee (ARAC) Airman Certification Standards (ACS) Working Group (WG), the FAA is reviewing and revising a number of its reference handbooks.

Handbooks currently under revision with an estimated release date of September 2021:

- FAA-H-8083-3, Airplane Flying Handbook

Handbooks currently under revision with an estimated release date of December 2021:

- FAA-H-8083-2, Risk Management Handbook
- FAA-H-8083-24, Small Unmanned Aircraft Systems Operating Handbook
- FAA-H-8083-29, Powered Parachute Flying Handbook

Handbooks currently under revision with an estimated release date of March 2021:

- FAA-H-8083-5, Weight-Shift Control Aircraft Flying Handbook

Handbooks currently under revision with an estimated release date of September 2022:

- FAA-H-8083-13, Glider Flying Handbook
- FAA-H-8083-15, Instrument Flying Handbook
- FAA-H-8083-25, Pilot's Handbook of Aeronautical Knowledge

Handbooks currently under revision with release dates TBD:

- FAA-H-8083-11, Balloon Flying Handbook
- FAA-H-8083-33, Powered-Lift Flying Handbook

Airman Knowledge Testing Supplement Revision Update

- There will be no supplement revisions in 2021.
- The current editions of the Airman Knowledge Testing Supplements are available here.

For previous versions of the *What's New and Upcoming in Airman Testing,* visit the Archives page.