Organisation de l'aviation civile internationale

NOTE DE TRAVAIL

GIACC/3-WP/6
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GROUPE SUR L'AVIATION INTERNATIONALE ET LES CHANGEMENTS CLIMATIQUES (GIACC)

TROISIÈME RÉUNION

Montréal, 17 – 19 février 2009

Point 2 : Examen des activités liées aux émissions provenant de l'aviation au sein de l'OACI et à l'échelle internationale

RENSEIGNEMENTS ACTUALISÉS SUR LES TRAVAUX DU CAEP EN MATIÈRE D'ENVIRONNEMENT

(Note présentée par le Secrétariat)

1. INTRODUCTION

1.1 La présente note contient des renseignements actualisés sur les activités du Comité de la protection de l'environnement en aviation (CAEP) de l'OACI concernant les émissions de CO_2 attribuables à l'aviation, en rapport avec les activités du Groupe sur l'aviation internationale et les changements climatiques (GIACC). Elle traite aussi des travaux continus visant à établir des objectifs technologiques et opérationnels en matière d'environnement et des travaux liés à l'évaluation des futures tendances des émissions de CO_2. Elle contient également une vue d'ensemble des travaux sur les éléments indicatifs relatifs aux mesures opérationnelles visant à réduire la consommation de carburant et des études sur les mesures fondées sur le marché.

2. TRAVAUX DU CAEP VISANT À ÉTABLIR DES OBJECTIFS

2.1 La septième réunion du CAEP (CAEP/7), tenue en février 2007, a décidé que des travaux devraient être menés pour établir des objectifs environnementaux à moyen terme (10 ans) et à long terme (20 ans) concernant la réduction de la consommation de carburant grâce aux progrès technologiques touchant les cellules et les moteurs, ainsi qu'à des mesures opérationnelles (par exemple l'amélioration de la gestion du trafic aérien). Pour garantir la transparence, il a été entendu que les objectifs seraient établis par des groupes d'experts indépendants (EI). Les améliorations technologiques et opérationnelles à moyen et à long terme seront incorporées dans l'évaluation des progrès vers les objectifs environnementaux de l'OACI[1] pour les années 2016, 2026 et 2036.

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[1] En ce qui concerne la protection de l'environnement, trois objectifs ont été adoptés et sont énoncés dans la Résolution A36-22 de l'Assemblée de l'OACI :

- limiter ou réduire le nombre de personnes exposées à un niveau élevé de bruit des aéronefs ;
- limiter ou réduire l'incidence des émissions de l'aviation sur la qualité de l'air locale ;
- limiter ou réduire l'incidence des émissions de gaz à effet de serre de l'aviation sur le climat mondial.

2.2 À la dernière réunion de son Groupe directeur (Seattle, 22 – 26 septembre 2008), le CAEP est convenu que la « mesure du rendement du carburant des systèmes d'aéronefs commerciaux » serait utilisée pour l'évaluation de l'objectif OACI concernant les émissions de CO_2 attribuables à l'aviation.

2.3 **Objectifs visant des progrès technologiques**

2.3.1 Pour ce qui est des travaux sur l'établissement d'objectifs technologiques à moyen et long terme (10 et 20 ans) concernant la consommation de carburant, la dernière réunion du Groupe directeur du CAEP est convenue d'une approche graduelle selon laquelle, comme première étape, les constructeurs (ICCAIA) rédigeront une note sur les progrès technologiques visant à réduire la consommation de carburant et présentant l'opinion préliminaire de l'industrie sur les perspectives de scénarios futurs sur la consommation de carburant. Ce texte figure à l'Appendice C de la présente note de travail.

2.3.2 L'opinion préliminaire de l'industrie résume les progrès technologiques continus concernant la réduction de la consommation de carburant qui sont en train d'être réalisés par les avionneurs et les motoristes dans les quatre domaines essentiels, soit la réduction du poids, les améliorations aérodynamiques, l'amélioration du rendement du carburant et l'optimisation des systèmes d'aéronef. L'opinion de l'industrie présente aussi des scénarios de réduction de la consommation de carburant pour la moyenne des aéronefs en production, dans lesquels les réductions vont de 0,95 % à 1,16 % par année de 2005 à 2050. Par comparaison, le Rapport spécial du GIEC de 1999 projetait une réduction moyenne de la consommation de carburant de 0,95 % par année pour la période 1997-2015 et de 0,57 % par année pour la période 2015-2050.

2.3.3 Il convient de noter que le WG/3 du CAEP (Émissions – Questions techniques) fait bon accueil à l'opinion des constructeurs présentée dans l'Appendice C et la considère comme un pas vers une bonne compréhension des procès technologiques possibles, et il constate ce qui suit :

a) le document présente des opinions préliminaires de l'industrie qui pourraient être utiles à la réunion GIACC/3 ;

b) certains membres du WG/3 du CAEP se sont inquiétés de l'absence de certaines précisions et hypothèses essentielles qui aideraient le GIACC dans ses délibérations ;

c) ces résultats préliminaires seront examinés plus en détail à l'atelier sur les technologies pour la réduction de la consommation de carburant, en mars 2009, dont les résultats seront présentés à la prochaine réunion du Groupe directeur du CAEP (juin 2009) et pourraient être disponibles pour la réunion GIACC/4.

2.3.4 Un groupe d'EI examinera les améliorations environnementales attendues en se fondant, mais sans s'y limiter, sur la liste récapitulative des progrès technologiques continus réalisés par les avionneurs et les motoristes, qui figure à l'Appendice A de la présente note.

2.4 **Objectifs opérationnels**

2.4.1 Un groupe d'EI a aussi été créé pour examiner les améliorations environnementales attendues des initiatives en gestion du trafic aérien (ATM) et d'autres initiatives opérationnelles à moyen terme (2016) et à long terme (2026). Les EI travaillent avec les experts ATM de la Direction de la navigation aérienne de l'OACI et des experts compétents de partout dans le monde. L'atelier initial s'est tenu les 4 et 5 décembre 2008, et le rapport des EI sur leur examen devrait être prêt à temps pour la réunion GIACC/4.

2.4.2 La présentation des résultats attendus de ces travaux devrait ressembler sensiblement à celle des résultats du Rapport spécial du GIEC, 1999 : *L'aviation et l'atmosphère planétaire*. Ce rapport du GIEC, dans son chapitre portant sur l'exploitation technique du transport aérien et ses relations avec les émissions, conclut que les améliorations prévues de l'ATM pourraient augmenter le rendement d'ensemble du carburant de 2 à 12 % et que les améliorations pouvant découler d'autres mesures opérationnelles étaient de 2 à 6 %. Ces chiffres devraient être actualisés et présenter des plages d'incertitude plus étroites que ceux qui ont été fournis il y a dix ans, étant donné que les initiatives opérationnelles sont mieux définies et que les capacités de modélisation sont renforcées. L'examen des EI devrait avoir lieu du 26 au 28 janvier 2009 et il est possible que les résultats initiaux puissent être mis à la disposition de la réunion GIACC/3.

2.4.3 Le groupe d'EI examinera les améliorations environnementales attendues en se fondant, mais sans s'y limiter, sur la liste récapitulative des initiatives ATM et autres initiatives opérationnelles, qui figure à l'Appendice B de la présente note.

2.5 **Mesure du rendement du carburant des systèmes d'aéronefs commerciaux**

2.5.1 L'établissement d'une mesure du rendement du carburant est lié aux objectifs technologiques concernant la consommation de carburant et aux objectifs opérationnels. Le CAEP a proposé la « mesure du rendement du carburant des systèmes d'aéronefs commerciaux » dans laquelle le produit de la charge utile et de la distance est le dénominateur et la masse du carburant est le numérateur :

Mesure du rendement du carburant des systèmes d'aéronefs commerciaux = charge utile × distance

2.5.2 La dernière réunion du Groupe directeur du CAEP a entériné l'utilisation de ce système de mesure pour l'évaluation des objectifs environnementaux par le biais des activités de modélisation du CAEP et elle est convenue que le CAEP devrait évaluer la nécessité d'affiner à l'avenir le système de mesure du rendement du carburant pour qu'il prenne en compte les analyses du cycle de vie complet du carburant utilisé.

2.6 **Évaluation des objectifs environnementaux**

2.6.1 Il faut disposer d'un cadre de modélisation solide pour l'évaluation des objectifs concernant les émissions de CO_2 attribuables à l'aviation internationale. Des progrès satisfaisants ont été accomplis par le CAEP dans l'élaboration de modèles. Dans le cadre du processus CAEP, divers modèles ont été évalués et jugés adéquats. Afin de garantir que des données d'entrées communes sont fournies à ces modèles, d'importants efforts ont été consentis pour actualiser les bases de données mondiales, notamment celles sur les aéroports, les mouvements d'aéronefs et les parcs aériens, et pour parvenir à un consensus à leur sujet.

2.6.2 Le CAEP concentre actuellement ses efforts à produire des projections quantifiées, qui seront utilisées dans les recommandations et décisions de politique. Les résultats de l'évaluation des objectifs environnementaux seront des projections de la consommation de carburant pour 2016, 2026 et 2036 par rapport à la base de référence de 2006, prenant en compte les améliorations technologiques et opérationnelles attendues découlant du processus d'examen par les EI, décrit aux paragraphes 2.3 et 2.4.

3. TRAVAUX DU CAEP SUR LA LISTE DES MESURES VISANT À RÉDUIRE LES ÉMISSIONS

3.1 Actualisation des orientations sur les possibilités opérationnelles de tenir la consommation de carburant au minimum et de réduire les émissions

3.1.1 En 2004, l'OACI a publié la circulaire *Possibilités opérationnelles de tenir la consommation de carburant au minimum et de réduire les émissions* (Cir 303). Les orientations que contient cette circulaire définissent et examinent différentes possibilités et techniques opérationnelles pour tenir au minimum la consommation de carburant et, par conséquent, les émissions de CO_2, dans les activités d'aviation civile. Elles portent notamment sur les opérations au sol et en vol, le matériel de servitude au sol (GSE) et les groupes auxiliaires de puissance (GAP), et traitent des mesures éventuelles pour faciliter l'élargissement de la mise en œuvre des possibilités opérationnelles.

3.1.2 Le CAEP s'emploie actuellement à préparer des orientations qui vont actualiser et remplacer la Circulaire 303, avec de nouveaux renseignements sur les initiatives en cours concernant la réduction de la consommation de carburant. La dernière réunion du Groupe directeur du CAEP est convenue que les nouvelles orientations vont non seulement fournir des informations actualisées sur les initiatives en cours, mais aussi étoffer les dispositions portant sur 1) la méthodologie d'évaluation des incidences environnementales appliquées au système CNS/ATM, 2) les orientations sur le calcul, l'évaluation et le compte rendu des émissions de l'aviation, et 3) les indicateurs environnementaux. Le projet d'orientations devrait être prêt à temps pour la réunion GIACC/4.

3.2 Mesures fondées sur le marché

3.2.1 Pour ce qui est des mesures fondées sur le marché, l'OACI a élaboré des politiques et des éléments indicatifs, et elle a recueilli des renseignements sur trois de ces mesures : 1) les mesures volontaires, 2) les redevances liées aux émissions, et 3) l'échange de droits d'émission.

3.2.2 En 2004, l'OACI a élaboré un accord volontaire type entre des industries aéronautiques et des organismes publics, et a recueilli et diffusé des renseignements sur des mesures volontaires prises par des États contractants et différentes parties prenantes pour réduire les émissions de CO_2 attribuables à l'aviation en 2007, en vue d'aider d'autres organismes à lancer des mesures semblables ou à renforcer celles qui sont en cours. En 2007, l'OACI a publié des orientations sur les redevances liées aux émissions locales (*Orientations sur les redevances liées aux émissions des moteurs d'aviation et à la qualité de l'air locale*, Doc 9884) et élaboré des orientations à suivre par les États pour inclure les émissions de l'aviation internationale dans leurs régimes d'échange de droits d'émission (*Orientations sur l'utilisation de l'échange de droits d'émission en aviation*, Doc 9885).

3.2.3 Le CAEP étudie actuellement des questions concernant la corrélation des régimes d'échange de droits d'émissions incorporant l'aviation. Par ailleurs, il étudie les diverses mesures de compensation des émissions pour atténuer les incidences de l'aviation sur les changements climatiques.

4. CONCLUSION

4.1 Les éléments du programme de travail du CAEP sont étroitement liés aux activités du GIACC, en particulier les travaux sur les objectifs opérationnels et technologiques concernant la consommation de carburant, l'évaluation des objectifs environnementaux, et les nouvelles orientations destinés à remplacer la Circulaire 303, qui appuieront l'établissement d'objectifs ambitieux mondiaux et d'une liste de mesures visant à réduire les émissions, respectivement. Il est important que le CAEP et le

GIACC continuent de collaborer pour maximiser l'efficacité dans ce domaine et tirer parti des synergies entre les activités des deux groupes.

5. SUITE À DONNER PAR LE GROUPE

5.1 Le groupe est invité à :

a) prendre note des renseignements figurant dans la présente note ;

b) étudier de quelle manière le CAEP pourrait soutenir davantage les activités du GIACC dans ses délibérations sur le Programme d'action de l'OACI.

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APPENDIX A

SUMMARY LIST OF TECHNOLOGICAL DEVELOPMENT

1. Weight Reduction using advanced materials, structural layout and manufacturing methods, including:

- Advanced light and hard alloys;
- New composite materials and manufacturing processes;
- Self healing materials;
- Smart structures;
- Nanotechnologies; and
- New joining processes.

2. Aerodynamic Improvements, including:

- Reduce local skin friction by maintaining laminar flow via NLF (Natural Laminar Flow) or HLFC (Hybrid Laminar Flow Control) and/or by reducing turbulent skin friction;
- Reduce wetted area while minimizing flow separation, optimize surface intersections/junctures and fuselage aft-body shapes, and use flow-control devices to minimize flow separation;
- Minimize manufacturing excrescences (including antennas);
- Optimize air inlet/exhaust devices; and
- Suitable wing-tip devices (winglets or wing tips).

3. Propulsion System and Power Generation Developments, including:

- Propulsive efficiency (decreasing fan pressure ratio and increasing the engine bypass ratio);
- Thermal efficiency (increasing engine pressure ratio); and
- Transmissive efficiency (improved component efficiencies).

4. Aircraft Configuration Optimization and Systems Development, including:

- More electric aircraft (bleedless engine, fuel cell, electric flight control); and
- Fly-by-Wire and Fly-by-Light

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APPENDIX B

SUMMARY LIST OF AIR TRAFFIC MANAGEMENT AND OTHER OPERATIONAL MEASURES

1. Air Traffic Management Initiatives, including:

- Flexible use of airspace
  - optimize and balance the use of airspace between civil and military users, through both strategic coordination and dynamic interaction;
- Reduced vertical separation minimum (RVSM)
  - reduce vertical separation to 1000 ft above FL 290 from the current 2000 ft, thereby providing six additional flight levels;
- RNAV and RNP (performance-based navigation:PBN)
  - exploit area navigation (RNAV) and required navigation performance (RNP) capabilities in aircraft and allows more efficient routes and aircraft trajectories that are not directly tied to ground-based navigation aids;
- Air traffic flow management (ATFM)
  - the implementation of strategic, tactical and pre-tactical measures aimed at organizing and handling traffic flows; and
- Terminal area design and management
  - the optimization of the terminal control area through improved design and management techniques.

2. Other Operational Measures accrued from optimization of airport/aircraft operations.

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APPENDIX C

PROGRESS REPORT ON AIRCRAFT TECHNOLOGIES FOR FUEL BURN REDUCTION

(Presented by ICCAIA in CAEP WG/3 Meeting in Tokyo – Nov 17-21, 2008)

Summary

- ICCAIA has observed there is increased interest in projecting what potential aviation emissions reductions could be in the mid and long term. In support of MODTF CAEP/8 Environmental Goals Assessment exercise, ICCAIA recently developed recommended scenarios of new and in-production aircraft fuel burn improvement over time.

- Significantly better consumption scenarios than the forecasted fuel burn made through the 1999 IPCC Special Report On Aviation were identified by ICCAIA to better reflect the current technology status and forecast. (Refer CAEP8_WG3_LTTG5_WP05 for more information).

- As an interim status to the Fuel Burn Technology Goals Review Process, this paper summarizes the on-going industry technology developments, which are being transitioned in the near future to upcoming products or are being studied for next-generation aircraft, in support of the fuel burn scenarios identified for the MODTF exercise.

- Dedicated and sustained research programs supported by funding bodies play a critical role in the continuous success of technology into maturity and their implementation within aviation industry.

1. INTRODUCTION

Aviation has voluntarily reduced its fuel consumption by a significant amount over the past forty years. These challenges have been met by aggressive revolutionary and evolutionary technology development while maintaining unprecedented levels of safety. ICCAIA is committed to further decreasing the environmental footprint of aviation and to supporting its customers in achieving their environmental commitments, including greenhouse gas emissions reduction goals. To achieve this, ICCAIA is dedicated to aggressive environmental objectives, specifically with regards to overall aircraft technology development and insertion when required maturity levels are achieved.

The purpose of this paper is to report to LTTG and WG3 the progress and status of on-going fuel burn reduction technology developments explored by different engine and airframe manufacturers which are being transitioned in the near future to the upcoming products. Promising and less mature technologies that are further out into the future are also summarized. These preliminary results will be further validated during the Fuel Burn Reduction Technology Workshop in March 2009 and Fuel Burn Reduction Technology Review in 2010.

The fuel burn technology developments covered herein are based on kerosene type fuels. No consideration have been given at this time to alternate fuels since current study focuses on fuel burn reduction technologies that reside on the aircraft itself. Any use of alternative fuels is assumed to be on a "drop in" basis. As "drop in" fuels reach the technology readiness for implementation, industry can adopt them.

2. TECHNOLOGY ADVANCES IN PRODUCTS ENTERING REVENUE SERVICE IN 2007 – 2015

Over the past forty years, aircraft and engine manufacturers have aggressively continued product development, with a key design driver being a focus on fuel burn reduction technologies. Extending this trend, newly certified aircraft entering revenue service in next 7 years will provide at least 15% fuel burn reduction relative to the products they replace. Some of these products just introduced or arriving in the near term are: Airbus A380, Sukhoi Super Jet 100, Boeing B787 family and B747-8, Airbus A350 family, Bombardier CRJ1000 and CSeries, Mitsubishi Regional Jet MRJ90, and Chinese Regional Jet ARJ21.

Specific airframe and engine technologies that contribute to the significant fuel burn reduction in these new products include:

- Natural Laminar Flow and other aerodynamic refinements such as blended winglets and raked wingtip
- Advanced aircraft systems, including Electric Aircraft Architecture and Advanced Fly-by-Wire control laws
- Composite materials and advanced metal alloys on primary structure components including wing and fuselage components
- Advanced Turbofan Engines with Higher Bypass Ratio configurations including geared and ungeared fan architectures
- Further Aircraft Configuration Optimization, integration

3. ADVANCES IN CORE TECHNOLOGIES UNDER DEVELOPMENT

Aviation, a domain dominated by multiform and sophisticated technologies, where complex optimization and trade-offs are involved, carries a significant challenge when assessing technology progress, as technologies require a thorough and complete life cycle assessment. Additionally, while individual technologies may provide unique and individual benefits, careful consideration must be given when assessing the potential benefit at aircraft level. Indeed, individual technology benefits are not necessarily cumulative. Any assessment requires an appropriate integration of all the various technologies, an evaluation of technology interactions and the subsequent benefits to the overall aircraft configuration, performance, airworthiness and safety.

Fuel burn reduction technologies can be attributed to developments in one of the four following Core Aircraft Technology Design Areas:

- Weight reduction using advanced materials and structural layout, including innovative manufacturing methods,

- Aerodynamic improvements resulting in lift/drag optimization and configuration refinements
- Engine specific fuel consumption (SFC) reduction: Propulsion and power-generation developments, and
- Aircraft configuration optimization and systems integration

Fuel burn technologies are also not “one size fits all”. The benefit for a specific technology will be dependent on aircraft and engine size, and mission design parameters. In general, aircraft and engine manufacturers are committed to introducing sufficiently mature technologies into service at the earliest possible practical time on existing or on entirely new configurations.

3.1 Advanced Materials, Structural Layout and Manufacturing Methods

Minimizing overall aircraft weight is a key driver for airframe design. Any excess weight requires the overall aircraft system to be oversized (e.g., resulting in higher wing area to lift the maximum takeoff gross weight, additional thrust for takeoff and cruise, and subsequent increases in drag and noise, and requirements for additional fuel to provide the same range.) Lighter and stronger materials are therefore enablers to enhanced aircraft performance and fuel burn.

The basic material properties (strength, fatigue behavior, damage tolerance, density, stiffness, etc.) are key to selecting the best material for a given airframe part. Furthermore, aspects such as manufacturability, repairability, cost, supplier availability and other environmental aspects (such as recycling expectations) also need to be considered.

For future aircraft airframes, a large range of materials, manufacturing processes and technologies are under investigation, with different maturity levels. Some examples of opportunities are:

- Advanced light and hard alloys (e.g., Aluminium-Lithium alloys, advanced Titanium alloys, Aluminium-Magnesium-Scandium alloys)
- New composite materials and manufacturing processes (e.g., thermoplastic, advanced thermosets)
- Self Healing Materials
- Smart structures (e.g., morphing, self-reacting structures, multi-functional structures)
- Nanotechnologies (e.g., surface treatment and protection, advanced composite materials) and
- New joining processes (e.g., Laser Beam Welding, Friction Stir Welding, advanced bonding).

To illustrate the progress made so far, back in the 1990s aircraft primary structure was composed of no more than about 10 per cent of composite materials. New and future products will contain close to (or more than) 50% of composite material, with a total of at least 70% of advanced materials. Continued and progressive improvements are made by the aviation industry to further consider advanced materials introduction into future aircraft and engines. The best material will be chosen for each application.

In addition to new materials, new manufacturing process such as the laser beam welding (LBW) has recently been introduced in the production of primary structure. Currently expanding to the commercial aircraft industry to complement or replace other conventional welding techniques or riveting processes, LBW improves the quality of the joining of metallic structure and offers opportunities to reduce aircraft weight.

3.2 Aerodynamic Improvements

Aerodynamic efficiency is a key driver for airframe design. Efficient aerodynamics allows an aircraft to carry a given payload further or to reduce the aircraft fuel consumption for a given range. Technologies associated with aerodynamic improvements are being explored by all aircraft manufacturers. They include: improved winglets or alternate wing-tip devices, optimization using advanced CFD (Computational Fluid Dynamics), excrescence drag reduction, laminar flow and turbulent-skin-friction reduction.

The typical breakdown of total airplane drag into the main drag components is shown in Fig. 1 for a large twin commercial aircraft configuration in the cruise condition. The main drag components are: lift-dependent (or induced) drag, shock-wave drag, excrescence drag and viscous (or profile) drag.

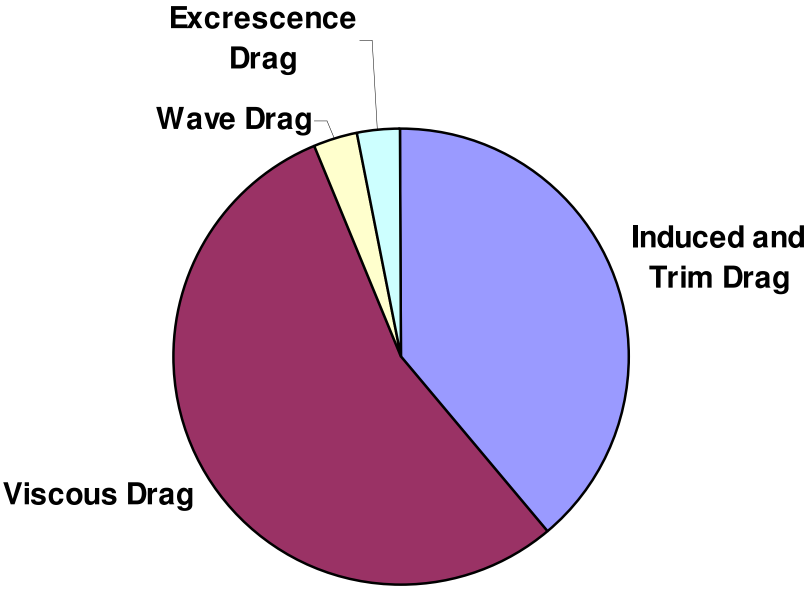

Figure 1 Typical Drag Breakdown for Subsonic Commercial Aircraft at Cruise Condition

Viscous and lift-dependent drags are the largest contributors to the total drag of subsonic aircraft.
For future airframes, a range of drag-reduction technologies are currently under investigation in these two dominant categories. Some examples of those technologies are given below.

<u>Viscous drag reduction</u> promises one of the largest areas for improved aircraft efficiency over the next 10 - 20 years. There are several opportunities for viscous drag reduction:

a) Reduce local skin friction by maintaining laminar flow via NLF (Natural Laminar Flow) or HLFC (Hybrid Laminar Flow Control) and/or by reducing turbulent skin friction (e.g., passively with riblets, or with active flow control, such as small low-energy plasma actuators or small oscillating-wall actuators)

b) Reduce wetted area while minimizing flow separation, optimize surface intersections/junctures and fuselage aft-body shapes, and use flow-control devices to minimize flow separation

c) Minimize manufacturing excrescences (including antennas), and

d) Optimize air inlet/exhaust devices.

Lift-dependent drag is dominated by physical wing span and by spanloading. Wing span is constrained by structural (weight) considerations as well as by airport infrastructure (e.g., terminal gate width and spacing between taxiways etc.) Advances in materials, structures and aerodynamics currently enable significant lift-dependent drag reduction by maximizing effective span extension, within airport constraints, using composites in primary wing structure. Suitable wing-tip devices (such as winglets or raked wing tips) together with appropriate spanloading can provide important increases in the effective aerodynamic span, resulting in reduced lift-dependent drag. Older-generation aircraft may have a large performance benefit with the addition of winglets; however, structural weight and aerodynamic optimization need to be combined to arrive at a best tip extension for a given airplane. In addition, for a given span, spanload tailoring is feasible with aeroelastic tailoring or variable camber employing trailing edge flaps or other devices throughout the mission including off-design operational conditions.

Aerodynamic drag benefits need to be traded against impact on manufacturing, aircraft weight, systems complexity, maintenance, reliability, and economical aspects to determine if a drag improvement results in a net benefit to the aircraft transportation system.

3.3 Engine SFC Reduction: Propulsion System and Power Generation Developments

Since the introduction of the gas turbine aero engine, fuel consumption has been improved year on year through improved efficiencies. Tomorrow's aero engines will continue to be further improved through insertion of advanced technology, as well as by introduction of novel engine architectures.

Generally, improvements in engine specific fuel consumption of aircraft engines can come from following three categories:

- Propulsive efficiency (decreasing fan pressure ratio and increasing the engine bypass ratio)
- Thermal efficiency (increasing engine pressure ratio)
- Transmissive efficiency (improved component efficiencies).

These three pathways for improvement as well as novel engine architectures are briefly discussed below. It should also be noted that focusing on improved SFC must be balanced by other (aircraft) design criteria to ensure that an overall net improvement in performance and customer acceptance is achieved. These design criteria include weight, drag, noise, and emissions, but also include operability, complexity, reliability, repairability, and cost of ownership.

Propulsive Efficiency

Propulsive efficiency is a measure of how efficiently the exhaust gas of the engine propels the aircraft. It is maximized by lowering the speed of the exhaust as close as possible to the speed of the aircraft. In future engines, propulsive efficiency improvements will continue to take place commensurate with the engine manufacturer's improvements in fan blade, fan case, and nacelle weight reductions, as well as drag control measures for the nacelles. Continued incorporation of composites or other light weight materials in the fan system will continue to provide weight reductions. However, tomorrow's engines are being optimized in the range of 10-12 bypass ratio. To continue to make propulsive efficiency improvements, either the nacelle system has to be revolutionized to reduce weight and drag, or the ducted nacelle approach needs to be eliminated. The former may facilitate the use of ultrahigh bypass ratio (UHBR) turbofans, while the latter infers the use of open rotor engines. Open rotor engines effectively run at a very high bypass ratio resulting in a very high propulsive efficiency and low SFC. However the removal of the nacelle introduces new challenges in installation (very large fan diameters requiring unique placement on the aircraft) and possible noise implications.

Thermal Efficiency

Thermal efficiency is a measure of how efficiently the energy content of the fuel can be converted to useful energy (gas-stream horsepower) for subsequently producing thrust. For turbofan engines, which today operate on a Brayton cycle, thermal efficiency is directly proportional to the engine's overall pressure ratio (OPR), or the level to which we can efficiently compress air within limitations set by the rest of the engine system. Today's commercial turbofan engines are limited in OPR to a level of about 50:1. Further increases in OPR will cause cooling air requirements to increase at a rate such that the energy discarded/lost by the cooling air overcomes the original benefit of increasing the OPR, and NOx emissions may become untenable due to associated increased gas temperatures. .

A further approach for improving thermal efficiency is related to manipulation of the Brayton cycle. This include concepts such as intercooling and recuperating (as discussed in 3.3.5 below), or via variable or adaptive cycle mechanism manipulation. All such concepts are being pursued in various demonstrator efforts by engine manufacturers.

Transmissive (Component Efficiency)

Engine manufacturers continue to improve on component efficiencies throughout the engine from mitigation of aerodynamic losses, or extensions of high-efficiency islands in the design space. The advances are a result of increased computing capability and increased analysis fidelity, and can lead to concepts such as increased stage loading to allow for blade and vane count reductions, or even entire elimination of a turbine or compressor stage.

Powerplant Installation effects

The impact of a powerplant, in term of fuel burn, is not only linked to its key parameters of propulsive and thermal efficiencies, but also other parameters. In fact, when regarding powerplant installation and integration effects, the engine manufacturer has to make, together with the airframer, a variety of compromises between parameters such as:

- Engine efficiency improvement versus weight
- Engine efficiency improvement versus drag from the engine's nacelle and interaction between nacelle and airframe
- Performance in cruise versus performance at other conditions in the mission (such as take-off)
- Energy extraction from engine (mechanical, electrical, and pneumatic, e.g., "hot" air for anti-ice /de-icing systems).

Engine Architecture Concepts under Consideration

Current engine manufacturers' focus includes the Advanced Turbofan (ATF), the Geared Turbofan (GTF), the (Counter-Rotating) Open Rotor engine, and Intercooled and Recuperated cycles. All of these concepts are being worked and are projected to have significant fuel burn improvement relative to today's engines. Further description of these architectures will be covered at the upcoming Fuel Burn Reduction Technology Workshop in early 2009.

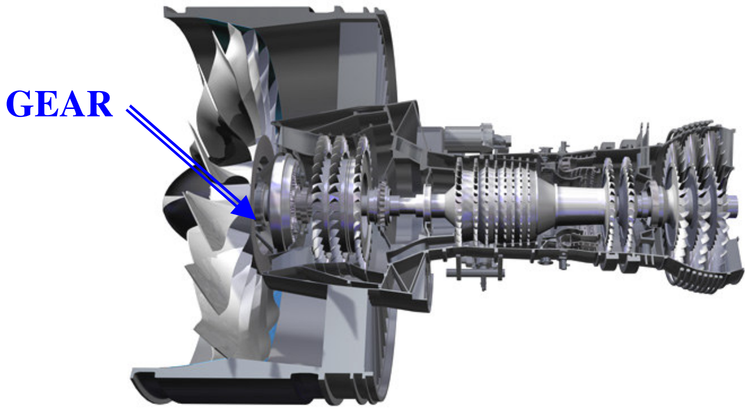

Figure 2 Typical GTF Cross-section

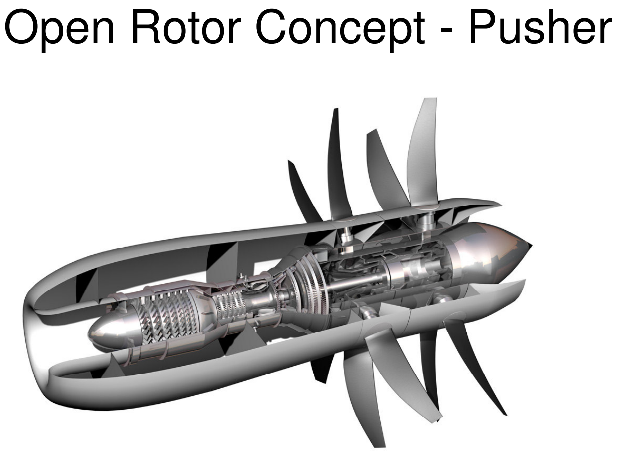

Figure 3 Typical Open Rotor Concept - Pusher

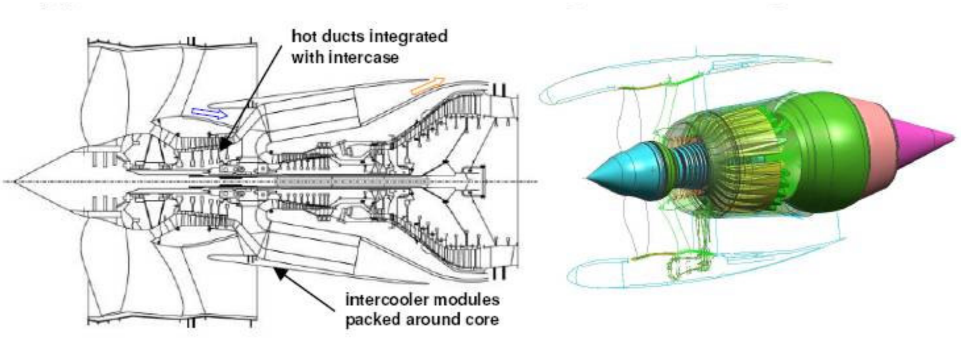

Figure 4 Possible Intercooler Aero Engine Configuration

3.4 Aircraft Configuration Optimizations and Systems Developments

Multi-disciplinary configuration optimizations through synergies between various disciplines are of significant importance and value when designing an aircraft with current standard aircraft configuration. Setting the design space with all the facts in mind while allowing design techniques that favour deeper exploration of the design space is of major importance.

Systems optimizations at the aircraft level are being explored continuously while ensuring that its implementation is justified for the given application and specific characteristics of the application. These are assessed using the life cycle cost modeling which can offer different conclusions for the same technology, being dependant on the aircraft and engine size, mission objectives and overall program and marketing requirements and objectives.

System optimization avenues that aircraft manufacturers are pursuing include:

- Even More Electric Aircraft (MEA)
    - Bleedless engine : as in medium term opportunities
    - Fuel cell : as a replacement for APU
    - Electric Flight Controls : as a replacement for hydraulic systems
- Active load alleviation through Fly-by-Wire control laws advancements
- Fly-by-Light (FBL)
- Integrated Utilities and multi functions components applications which offers parts count reduction and overall a/c efficiency improvement

Achievement of further significant improvements in aircraft efficiency may require future consideration of novel aircraft configurations (such as blended-wing body, strut-braced or spanloader aircraft concepts) to allow additional significant synergism between the core aircraft technologies. In addition to improving near-term efficiency, aircraft and engine manufacturers are involved in studies that evaluate alternate aircraft configurations.

Development to application and operational readiness of the technologies described in this section is highly dependent on the dedicated and sustained research and technology development at and by aircraft manufacturers and their suppliers, airline operators, government research agencies, airworthiness authorities and academia. Several large-scale programs involving all these important technology partners have been defined in Europe, United States, Japan etc, towards maturing some of the most promising core technologies in the next 10 – 20 years and their dedicated and sustained support is critical to the continued success of technology maturity and implementation.

4. TECHNOLOGY TRANSITION TO PRODUCT

Technology development and implementation into the operational fleet as retrofit or incorporated into an entirely new aircraft spanning over many years and requiring large and consistent funding, can be divided into two major steps

a) The first part is to start with a novel technology concept (or aircraft configuration concept) and to develop it to the point that it can be demonstrated in a realistic environment. While novel technologies are theoretically interesting, they are only partially proven and based on analytical and laboratory type analysis (i.e., CFD, and wind tunnel test with scaled models). This part is typically accomplished by national research organizations.

b) The second part is to transition the technology concept from the demonstration phase into a viable product. This is where industry takes over and bridges the gap between laboratory and market, maximizing the benefits while minimizing the industrialization roadblock and costs. Particular additional aspects that are evaluated include: Safety, Durability, Operability, Maintenance Costs, Production Costs, Reliability, Risk, Environment, Certification, and Market acceptance. The end objective being to assess and address concerns and problems, reduce the risks, identify the key fields or items where priority should be given and in the end, to demonstrate an overall benefit for the business case and increases possibility of novel configuration selection.

5. TRADE-OFFS

In the establishments of the fuel burn reduction trends and goals, one must take into account the effects that these technologies have relative to other environmental parameters. The trade offs were previously discussed within LTTG, WG3 and CAEP to a large extent. When new generation of aircraft and engines have been developed, manufacturers have worked in close cooperation to ensure the new generation is more environmentally friendly than the previous generation. Noise levels, local air quality emissions and fuel burn have all improved over the past decades. When making decisions on the appropriate trade-offs and investments in research, the industry has been guided by the various requirements defined by all the aviation stakeholders (operators, airports, populations close to the airport, passengers, etc). In general, the desires of those stakeholders have been aligned in the same directions. All environmental parameters are important and, ideally, manufacturers would like to select the solution that provides benefits to all of them. However, some of these environmental factors and other design drivers are inter-related and can go in different directions.

An example of environmental trades is fuel burn reduction versus noise reduction. For a turbofan engine, noise generally reduces with increasing fan diameter, whereas the increasing weight and drag mean that there is an optimum fan size for minimum fuel burn. The open rotor engine offers a step change improvement in fuel burn, but the lack of a nacelle means that it will probably not match an advanced turbofan on noise. Industry is aware of the challenges associated with possible trade-offs and all stakeholders need to be involved to achieve a satisfactory solution.

6. FUEL CONSUMPTION TECHNOLOGY SCENARIOS

Based on improvements in core aircraft technologies identified above and the overall assessment of their benefits, ICCAIA recently concluded in an initial assessment, that fuel consumption reduction has been stronger than was anticipated by the 1999 IPCC report. The 1999 IPCC scenario may be considered as being primarily useful for historical reference. Because of this, new fuel burn reduction technology scenarios can better reflect the current technology ambitions. Shown in figure 5 (Ref CAEP8_WG3_LTTG5_WP05) below are three fuel burn technology scenarios (“1999”, “A”, and “B”). 1999 is the 1999 IPCC scenario that produces 0.95% year by year fuel consumption reduction between 1997 and 2015, and 0.57% per year reduction from 2015 to 2050. New Scenario A relies on intensive current and future research efforts and introduction of improved products reflecting actual achievements or ambitious targets and produces a 0.96% per year fuel burn reduction. New Scenario B requires even higher research commitment and effort levels than Scenario A, and includes the assumption that ambitious EU and US research programs will be funded and successful. Scenario B produces on average a 1.16% per year fuel burn reduction. All three scenarios are shown with a base year of 2006, are projected to 2050, and represent smoothed improvements of the in-production fleet (newly produced aircraft entering the operating fleet in a given year as required for aircraft replacement and fleet growth).

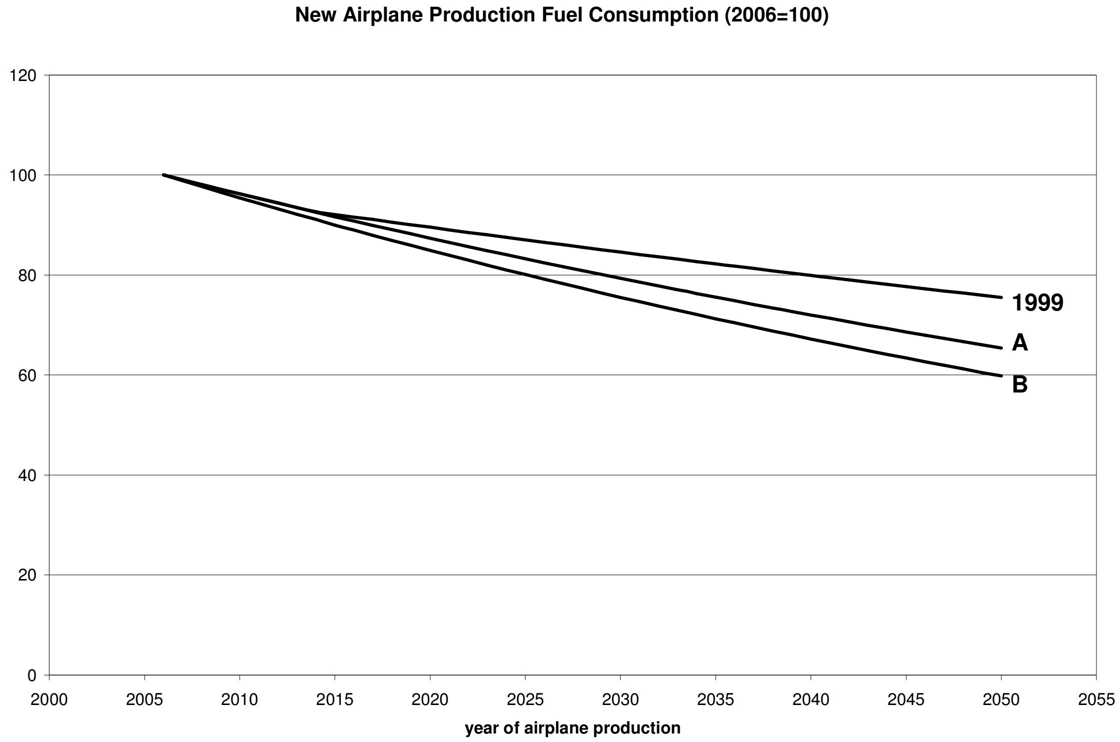

Figure 5 New Production Aircraft Fuel Consumption Scenarios

7. CONCLUSION

A list of significant improvements in aircraft core technologies (both in airframe and engine areas) has been identified. Development and implementation of these technologies when the appropriate readiness level is achieved will benefit current new-generation of aircraft as well as the next generation of aircraft. Numbers were provided to illustrate individual or specific technology improvements in terms of fuel burn. Those numbers are preliminary figures, and represent the best estimate from manufacturers at the time of writing. Those figures may be subject to evolution as the technology maturity increases.

Aircraft industry will continue to aggressively pursue these technologies in its commitment to further decrease the environmental footprint of aviation and to support its customers in achieving their environmental commitments, including greenhouse gas emissions reduction goals.

To achieve this, ICCAIA is dedicated to aggressive environmental objectives, in particular in terms of overall aircraft technology development and insertion, while also relying on the research establishment progression to bring technologies to a mature level that can make the technologies implementation and transition achievable on both new aeronautical products and on the existing fleet.

This paper is a progress report that and will be followed by a report based on the Fuel Burn Reduction Technology Workshop in March 2009 and the Fuel Burn Reduction Technology Review in 2010.

— END —