Organización de Aviación Civil Internacional

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NOTA DE ESTUDIO

GRUPO SOBRE LA AVIACIÓN INTERNACIONAL Y EL CAMBIO CLIMÁTICO (GIACC)

TERCERA REUNIÓN

Montreal, 17 - 19 de febrero de 2009

Cuestión 2 del orden del día: **Examen de las actividades relacionadas con las emisiones de la aviación, en la OACI e internacionalmente**

INFORMACIÓN ACTUALIZADA SOBRE EL TRABAJO AMBIENTAL DEL CAEP

(Nota presentada por la Secretaría)

1. INTRODUCCIÓN

1.1 En esta nota se proporciona información actualizada acerca de las actividades del Comité sobre la protección del medio ambiente y la aviación (CAEP) de la OACI, en relación con las emisiones de CO_2 de la aviación en el contexto de las actividades del Grupo sobre la aviación internacional y el cambio climático (GIACC). Se incluye el trabajo en curso relativo al establecimiento de metas tecnológicas y operacionales en materia ambiental y la labor de evaluación de las futuras tendencias de las emisiones de CO_2. Esta nota también contiene un resumen del trabajo correspondiente a los textos de orientación sobre medidas operacionales para reducir el consumo de combustible y a los estudios sobre medidas basadas en criterios de mercado.

2. TRABAJO DEL CAEP RELATIVO AL ESTABLECIMIENTO DE METAS

2.1 En la séptima reunión del CAEP (CAEP/7) celebrada en febrero de 2007, se decidió que debía llevarse a cabo trabajo para establecer metas ambientales de mediano y largo plazos (10 y 20 años, respectivamente) para reducir el consumo de combustible por medio del desarrollo de tecnología de células y motores, así como a través de medidas operacionales (p. ej., mejorando la gestión del tránsito aéreo). Para asegurarse de que haya transparencia, se convino en que las metas serían establecidas por grupos de expertos independientes (IE). Las mejoras tecnológicas y operacionales de mediano y largo plazos se incorporarán en la evaluación del avance logrado en alcanzar las metas ambientales[1] de la OACI para los años 2016, 2026, 2036.

[1] Se han adoptado tres metas para la protección del medio ambiente, de conformidad con lo establecido en la Resolución A36-22 de la Asamblea de la OACI:

- limitar o reducir la cantidad de personas afectadas por el ruido considerable de las aeronaves;
- limitar o reducir el impacto de las emisiones de la aviación en la calidad del aire local; y
- limitar o reducir las repercusiones de las emisiones de gases de efecto invernadero de la aviación en el clima mundial.

2.2 El CAEP, en la última reunión de su Grupo directivo (SG) (Seattle, 22-26 de septiembre de 2008), convino en que se utilizaría la ecuación para medir el rendimiento de combustible de los sistemas de aeronaves comerciales con la finalidad de evaluar la meta de la OACI relativa a las emisiones de CO_2 procedentes de la aviación.

2.3 **Metas de desarrollo de tecnología**

2.3.1 Para el trabajo relacionado con el establecimiento de metas tecnológicas de mediano y largo plazos (10 y 20 años, respectivamente) para el consumo de combustible, en la última reunión del SG del CAEP se acordó un enfoque en etapas mediante el cual, como primer paso, los fabricantes (ICCAIA) prepararían una nota sobre los avances tecnológicos que permitirán reducir el consumo de combustible, en la que se incluiría un análisis preliminar de la industria sobre las perspectivas de consumo de combustible en el futuro. En el Apéndice C figura la nota en cuestión.

2.3.2 En el análisis preliminar de la industria se resumen las tecnologías en curso para reducir el consumo de combustible que los fabricantes de aeronaves y motores están desarrollando en las cuatro áreas afines de reducción de la masa, mejoras aerodinámicas, mayor rendimiento de combustible de los motores y optimización del sistema de aeronaves. En el análisis de la industria también se ofrecen las perspectivas de reducción de consumo de combustible de aeronaves comunes en producción, reducción que oscila entre el 0,95% y el 1,16% anual para 2005-2050. Con fines comparativos, en el Informe especial del IPCC de 1999 se predijo una reducción promedio en el consumo de combustible del 0,95% anual para 1997-2015 y del 0,57% anual para 2015-2050.

2.3.3 Es importante tomar nota de que el WG3 (Grupo de trabajo técnico sobre emisiones) del CAEP vio el análisis de los fabricantes que figura en el Apéndice C como un paso para entender bien los posibles avances tecnológicos, tomando nota de que:

a) el documento ofrece un análisis inicial de la industria que puede ser de ayuda en la reunión GIACC/3;

b) algunos miembros del WG3 del CAEP expresaron preocupación en cuanto a que faltan algunos detalles e hipótesis esenciales que podrían ayudar al GIACC en sus deliberaciones; y

c) estos resultados preliminares se examinarán más a fondo durante el Seminario práctico sobre tecnologías de reducción del consumo de combustible, que se celebrará en marzo de 2009 y cuyos resultados se presentarán ante la próxima reunión del SG del CAEP (en junio de 2009) y podrían estar disponibles para la reunión GIACC/4.

2.3.4 El grupo de expertos independientes (IE) examinará las mejoras ambientales previstas a partir de, entre otros, la lista resumida de las tecnologías en curso que los fabricantes de aeronaves y de motores están desarrollando, la cual figura en el Apéndice A de esta nota de estudio.

2.4 **Metas operacionales**

2.4.1 También se estableció un grupo de expertos independientes (IE) para examinar las mejoras ambientales que se esperan de las iniciativas de gestión del tránsito aéreo (ATM) y de otras de índole operacional para el mediano y largo plazos (2016 y 2026, respectivamente). Los expertos independientes están trabajando con los expertos en ATM de la Dirección de navegación aérea de la OACI, así como con expertos competentes de todo el mundo. El seminario práctico inicial se celebró el 4 y 5 de diciembre de 2008 y se espera que el informe con el examen de los expertos independientes estará listo para la reunión GIACC/4.

2.4.2 El formato de los resultados que se esperan de este trabajo deberá parecerse algo al del Informe Especial del IPCC sobre la Aviación y la Atmósfera Global publicado en 1999. Ese informe del IPCC, en su capítulo sobre “las operaciones del transporte aéreo y la relación con las emisiones”, concluye que las mejoras previstas para la ATM podrían mejorar el rendimiento de combustible total en 2-12% y que las posibilidades de otras medidas operacionales se traducían en 2-6%. Se espera que estas cifras se actualicen y den menores márgenes de incertidumbre respecto de lo que se proporcionó hace 10 años, como resultado de una mejor definición de las iniciativas operacionales y de mejores capacidades de elaboración de modelos. El examen de los expertos independientes se tiene programado del 26 al 28 de enero de 2009 y sus resultados iniciales podrían estar disponibles, de ser posible, para la reunión GIACC/3.

2.4.3 El grupo de expertos independientes examinará las mejoras ambientales previstas a partir de, entre otros, la lista resumida de las iniciativas de gestión del tránsito aéreo (ATM) y de otras de índole operacional que figura en el Apéndice B de esta nota de estudio.

2.5 Ecuación para medir el rendimiento de combustible de los sistemas de aeronaves comerciales

2.5.1 El establecimiento de una ecuación para medir el rendimiento del combustible se relaciona con las metas tecnológicas de consumo de combustible y las metas operacionales. El CAEP propuso una ecuación para medir el rendimiento de combustible de los sistemas de aeronaves comerciales que emplea el producto de la carga de pago y la distancia como denominador y la masa de combustible utilizado como numerador:

Rendimiento de combustible de los sistemas de aeronaves comerciales = masa de combustible utilizado/
carga de pago x distancia

2.5.2 En la última reunión del SG del CAEP se aprobó el uso de esta ecuación para evaluar las metas ambientales a través de las actividades de elaboración de modelos del CAEP y se convino en que dicho Comité evaluaría la necesidad de refinar en el futuro la ecuación de rendimiento de combustible para abarcar el análisis del ciclo de vida completo del combustible empleado.

2.6. Evaluación de las metas ambientales

2.6.1 Se requiere un marco sólido de elaboración de modelos para evaluar las metas relativas a las emisiones de CO_2 procedentes de la aviación internacional. En el CAEP, se ha logrado un avance satisfactorio respecto del desarrollo de modelos. Se han evaluado varios modelos y se encontró que éstos se ajustan al proceso del CAEP. Para garantizar que dichos modelos funcionen a partir del suministro de datos comunes, se ha hecho un gran esfuerzo por actualizar las bases de datos mundiales, como las de los aeropuertos, los movimientos de aeronaves y las de la flota aérea, y por llegar a un consenso respecto de dichas bases de datos.

2.6.2 Actualmente, el CAEP está concentrado en producir proyecciones cuantificadas que se utilizarán en las recomendaciones y decisiones sobre definición de políticas. La evaluación de las metas ambientales dará como resultado proyecciones de consumo de combustible para 2016, 2026 y 2036, relativas al año de referencia 2006, en las que se incorporarán las mejoras tecnológicas y operacionales previstas que resulten del proceso de examen de los expertos independientes, de acuerdo con los párrafos 2.3 y 2.4.

3. TRABAJO DEL CAEP RELATIVO A LA LISTA DE MEDIDAS PARA REDUCIR LAS EMISIONES

3.1 Información actualizada referente a la orientación sobre las oportunidades operacionales para minimizar el consumo de combustible y reducir las emisiones

3.1.1 En 2004, la OACI publicó *Oportunidades operacionales para minimizar el consumo de combustible y reducir las emisiones* (Circ 303). En la orientación se determinan y examinan varias oportunidades y técnicas operacionales para minimizar el consumo de combustible y, por lo tanto, las emisiones de CO_2 en las operaciones de la aviación civil. Entre las operaciones que abarca la orientación figuran: las operaciones de base terrestre y en vuelo de las aeronaves, el equipo auxiliar de tierra (GSE) y los grupos auxiliares de energía (APU), incluyendo posibles medidas para facilitar su aplicación más amplia.

3.1.2 En el presente, el CAEP prepara orientación para actualizar y reemplazar la Circular 303 por nueva información sobre las iniciativas actuales relacionadas con la reducción del consumo de combustible. En la última reunión del SG del CAEP se convino en que la nueva orientación no sólo ofrecería información actualizada sobre las iniciativas actuales sino, también, ampliaría las disposiciones que cubren 1) la metodología de evaluación del impacto ambiental aplicada a comunicaciones, navegación y vigilancia/gestión del tránsito aéreo (CNS/ATM), 2) la orientación sobre el cálculo y la evaluación de las emisiones de la aviación y la presentación de informes sobre dichas emisiones y 3) los indicadores ambientales. Se prevé que el proyecto de orientación estará listo para la reunión GIACC/4.

3.2 Medidas basadas en criterios de mercado

3.2.1 En relación con las medidas basadas en criterios de mercado, la OACI ha elaborado políticas y textos de orientación y recopilado información sobre las tres medidas basadas en criterios de mercado: 1) medidas voluntarias, 2) derechos relacionados con las emisiones y 3) comercio de derechos de emisión.

3.2.2 La OACI preparó en 2004 una plantilla para los acuerdos voluntarios entre las industrias de aviación y las organizaciones públicas. Recopiló y difundió información sobre las medidas voluntarias tomadas en 2007 por los Estados contratantes y varios interesados directos para reducir las emisiones de CO_2 de la aviación, con la intención de ayudar a otras entidades a iniciar medidas similares o mejorar las actuales. En 2007, la OACI publicó orientación sobre los derechos relacionados con las emisiones locales (*Orientación sobre derechos por emisiones de las aeronaves relacionados con la calidad del aire local*, Doc 9884) y se preparó orientación para uso de los Estados a fin de que incorporaran las emisiones de la aviación internacional en sus planes de comercio de derechos (*Orientación sobre el uso del comercio de derechos de emisión para la aviación*, Doc 9885).

3.2.3 Actualmente, el CAEP está estudiando las cuestiones relacionadas con la interrelación de los planes de comercio de derechos de emisión que incluyan a la aviación. También, está examinando las diferentes medidas para contrarrestar las emisiones para reducir los efectos de la aviación en el cambio climático.

4. CONCLUSIÓN

4.1 Los elementos del programa de trabajo del CAEP se relacionan estrechamente con las actividades del GIACC, en especial, con el trabajo relativo a las tecnologías de reducción de consumo de combustible y a las metas operacionales; la evaluación de las metas ambientales; y la nueva orientación que reemplazará a la Circular 303, lo que ayudará a definir las metas mundiales a las que se aspira y se utilizará en la lista de medidas destinadas a reducir las emisiones, respectivamente. Es importante que el CAEP y el GIACC sigan cooperando para optimizar la eficiencia en esta área y apalancar las sinergias entre las actividades de los dos grupos.

5. MEDIDAS PROPUESTAS AL GRUPO

5.1 Se invita al grupo a:

a) tomar nota de la información de este documento; y

b) considerar cómo podría el CAEP proporcionar apoyo adicional en las actividades del GIACC durante las deliberaciones en torno al Programa de acción de la 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.

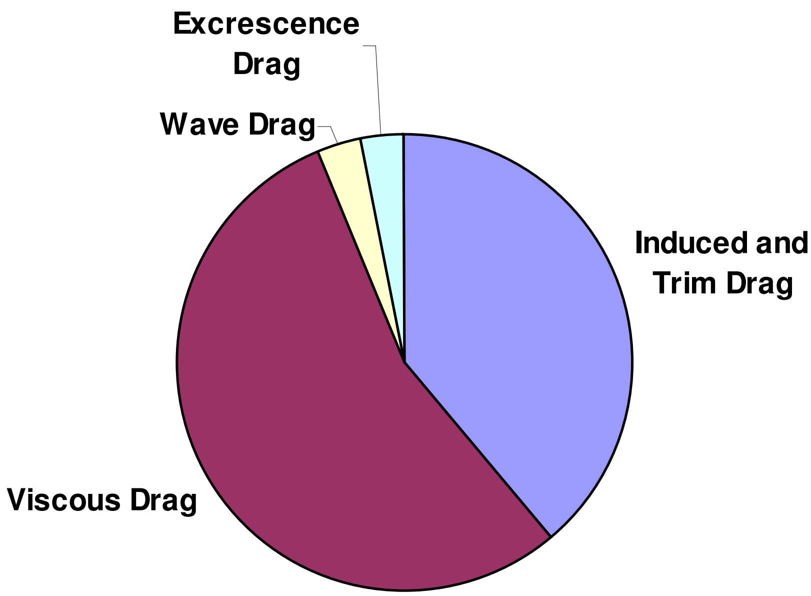

Figure 1 Typical Drag Breakdown for Subsonic Commercial Aircraft at Cruise Condition

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.

Viscous drag reduction 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.

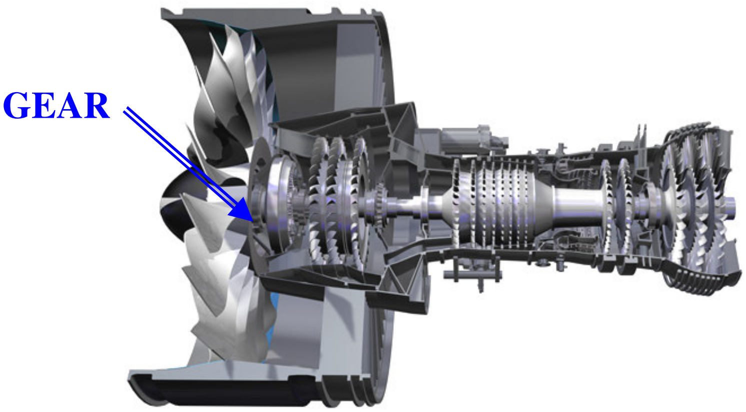

Figure 2 Typical GTF Cross-section

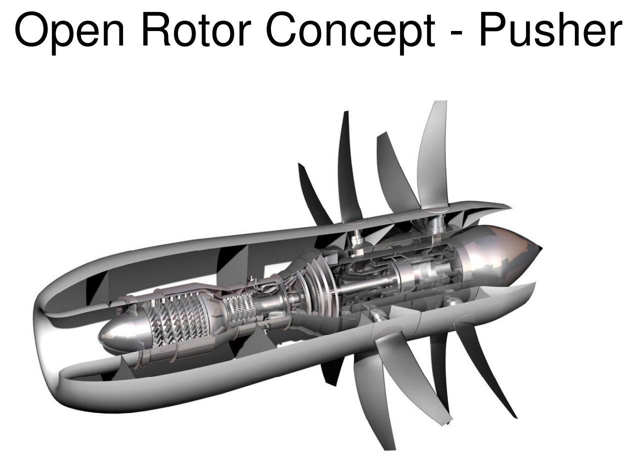

Figure 3 Typical Open Rotor Concept - Pusher

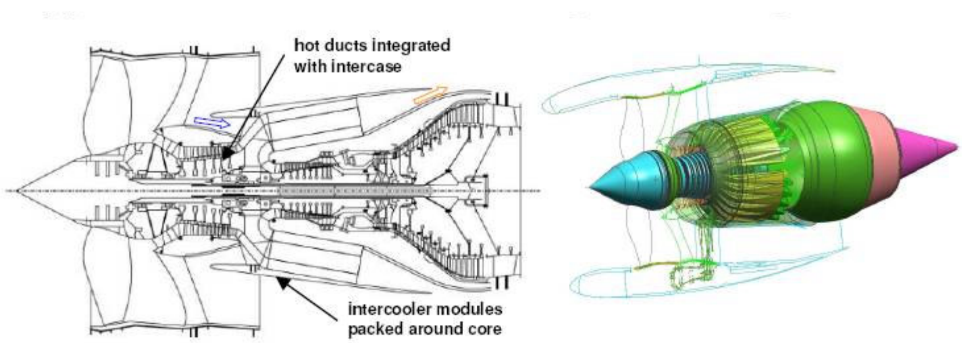

Figure 4 Possible Intercooler Aero Engine Configuration

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).

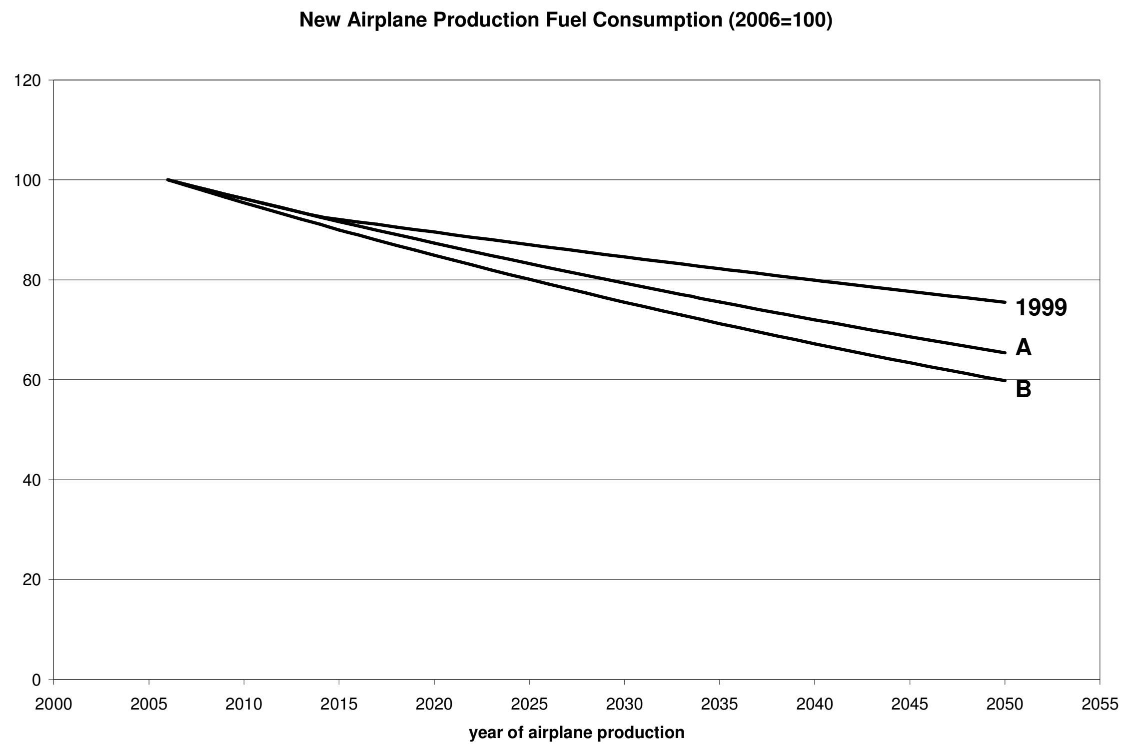

Figure 5 New Production Aircraft Fuel Consumption Scenarios

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 —