国际航空与气候变化组（GIACC）

第三次会议

2009 年 2 月 17 日至 19 日，蒙特利尔

议程项目 2：审查国际民航组织内部和国际上与航空排放有关的活动

关于航空环境保护委员会环境工作的最新情况

（由秘书处提交）

1. 引言

1.1 本文件提供了国际民航组织航空环境保护委员会（CAEP）在与国际航空与气候变化组（GIACC）各项活动有关的航空二氧化碳排放方面的各项活动的最新情况。它包含了制定技术及运行环境目标方面正在开展的工作，以及与评估二氧化碳排放未来趋势有关的工作。本文件还包含了减少燃油消耗的运行措施的指导材料，以及对基于市场措施的研究等工作的总体情况。

2. 航空环境保护委员会关于制定目标的工作

2.1 2007 年 2 月举行的航空环境保护委员会第七次会议（CAEP/7）决定，应通过机体和发动机的技术开发，并通过各种运行措施（如：改进空中交通管理）来开展工作，制定与减少燃油消耗有关的中期（10 年）和长期（20 年）环境目标。为了确保透明度，会议商定，各项目标将由独立专家小组（IE）制定。中期和长期的技术和运行改进工作，将纳入对实现国际民航组织 2016 年、2026 年、2036 年的环境目标[1]的进展情况进行的评估当中。

2.2 航空环境保护委员会在其指导小组（SG）的上次会议（2008 年 9 月 22 日至 26 日，西雅图）上商定，将用“商业航空器系统燃油效率指标”做为评估国际民航组织与航空二氧化碳排放有关的目标的燃油效率指标。

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[1] 根据国际民航组织大会第 A36-22 号决议，为环境保护通过了三个目标：
- 限制或减少受到严重的航空器噪声影响的人数；
- 限制或减少航空器排放对当地空气质量的影响；和
- 限制或减少航空温室气体排放对全球气候的影响。

2.3 技术发展目标

2.3.1 对于制定燃油消耗的中期和长期（10 年和 20 年）技术目标的工作，航空环境保护委员会指导小组的上次会议商定了一个分阶段进行的做法，作为第一步，制造商（宇航工业协会国际协调理事会（ICCAIA））将拟定一份关于减少燃油消耗方面技术进步的文件，其中有业界对未来燃油消耗设想各种前景的初步意见。这份文件载于本工作文件附录 C。

2.3.2 业界的初步意见概况了航空器和发动机制造商在减少重量、气动力改进、发动机燃油效率改进以及优化航空器系统四个核心领域，正在开展的减少燃油消耗的技术开发情况。业界的意见还提出了 2005 年至 2050 年，在产航空器每年平均减少 0.95％至 1.16％的燃油消耗的设想。为了进行对比，1999 年政府间气候变化专门委员会特别报告预计，1997 年至 2015 年每年的平均燃油消耗减少 0.95％，而 2015 年至 2050 年则为 0.57％。

2.3.3 应当谨慎注意到，航空环境保护委员会第三工作组（排放技术工作组）对附录 C 所载的制造商的意见表示了欢迎，以此做为形成全面理解潜在技术进步的一个步骤，并指出：

a) 文件提供的业界的初步意见可能有助于国际航空与气候变化组的第三次会议；

b) 航空环境保护委员会第三工作组的一些成员，对缺乏有助于国际航空与气候变化组开展审议的某些重要细节和设想表示了关切；和

c) 在 2009 年 3 月的减少燃油消耗的技术讲习班期间，将进一步审议这些初步结果，审议结果将提交给航空环境保护委员会指导小组的下次会议（2009 年 6 月），并可能提供给国际航空与气候变化组第四次会议。

2.3.4 一个独立专家组将根据但不限于本工作文件附录 A 所载的航空器和发动机制造商正在进行的技术开发的摘要目录，审议环境方面的预计改进情况。

2.4 运行目标

2.4.1 已经成立了一个独立专家小组，以便审议预计空中交通管理（ATM）及其它运行举措的中期（2016 年）和长期（2026 年）的环境方面的改进。独立专家组正在与国际民航组织空中航行局的空中交通管理专家及世界各地的有关专家进行合作。首次讲习班是在 2008 年 12 月 4 日至 5 日举行的，预计独立专家组的审议报告将会及时提交给国际航空与气候变化组第四次会议。

2.4.2 预计这项工作成果的形式与 1999 年政府间气候变化专门委员会关于航空和全球大气特别报告的形式类似。在政府间气候变化专门委员会的那份报告中，其有关“航空运输运行及与排放的关系”一章的结论是，预计空中交通管理的改进可能会把总体燃油效率提高 2％至 12％，而对其它运行措施的潜力则是 2％至 6％。鉴于对运行举措的更好界定和模型制做能力的改进，预计这些数字将会得到更新，相对于十年前提供的数字，其不确定的区间将会变窄。 独立专家组的审议定于 2009 年 1 月 26 日至 28 日进行，如有可能的话，其初步的结果将提供给国际航空与气候变化组第三次会议。

2.4.3 独立专家组将根据但不限于本工作文件附录 B 所载的空中交通管理及其它运行举措的摘要目录，审议环境方面的预期改进情况。

2.5 商业航空器系统燃油效率指标

2.5.1 燃油效率指标是相对于燃油消耗技术目标及运行目标而制定的。航空环境保护委员会提出的“商业航空器系统燃油效率指标”，采用业载与距离的乘积做分母，用燃油质量做分子：

商业航空器系统燃油效率指标＝消耗的燃油质量/业载 × 距离

2.5.2 航空环境保护委员会指导小组的上次会议核准了将这一指标用于航空环境保护委员会制做模型活动的环境目标评估，并商定航空环境保护委员会应评估今后对燃油效率指标进行细致调整的必要性，以便包含对所用燃油的完整循环周期分析。

2.6 对环境目标的评估

2.6.1 目前，需要一个健全的制做模型的框架，对来自国际航空的二氧化碳排放开展目标评估。航空环境保护委员会内部的模型开发已经取得了令人满意的进展。已经评估了各种模型，并发现它们均符合航空环境保护委员会的工作进程。为了确保这些模型通过共同投入发挥作用，已经做出了巨大的努力，对机场、航空器起降和机队之类的全球数据库进行更新并达成共识。

2.6.2 目前，航空环境保护委员会正在集中精力，拟定用于政策建议和决定的量化预测。对环境目标评估的结果将作为相对于 2006 年的基线，结合第 2.3 段和第 2.4 段中的独立专家审议过程中产生的技术和运行方面的预计改进，对 2016 年、2026 年和 2036 年开展燃油消耗预测。

3. 航空环境保护委员会关于减少排放的措施清单的工作

3.1 关于最大限度减少燃油使用和排放的运行机会的指导的最新情况

3.1.1 2004 年，国际民航组织出版了《*最大限度减少燃油用量和减少排放的运行机会*》（303 号通告）。这一指南查明并审议了最大限度减少民用航空运行的燃油消耗，从而减少二氧化碳排放的各种运行机会和技术。指导中涵盖的运行有：地面和飞行中的航空器运行、地面服务设备（GSE）以及辅助动力装置（APUs），同时具有便利其更广泛应用的可能的行动。

3.1.2 目前，航空环境保护委员会正在拟定指南，将用目前有关减少燃油消耗的各项举措的新信息，对 303 号通告进行更新并取而代之。航空环境保护委员会指导小组的上次会议商定，新指南将不仅提供对目前举措的更新，还将扩展到一些规定，将涵盖：1）适用于通信、导航和监视/空中交通管理的环境影响评估方法，2）关于计算、评估和报告航空排放的指南，和 3）环境指标。预计指南草案将及时提供给国际航空与气候变化组第四次会议。

3.2 基于市场的措施

3.2.1 关于基于市场的措施，国际民航组织已经制定了各项政策和指导材料，并一直在收集关于 3 项基于市场的措施方面的信息：1）自愿措施；2）与排放有关的收费；和 3）排放权交易。

3.2.2 2004 年，国际民航组织为航空业界与公共组织之间的自愿协议拟定了一个模板，并收集和散

发了各缔约国和不同利害攸关方在 2007 年减少航空二氧化碳排放的自愿行动的信息，以期帮助其它实体采取类似措施或改进其目前的措施。2007 年，国际民航组织出版了与当地航空排放有关的收费指南（*《与当地空气质量有关的航空器排放收费指南》*，Doc 9884 号文件），并制定了将国际航空排放纳入交易计划的指南（*《航空排放权交易使用指南》*，Doc 9885 号文件）供各国使用。

3.2.3 目前，航空环境保护委员会正在研究包括航空在内的与连结各种排放权交易计划有关的问题。同时，它还在审议各种排放抵消措施，以便减少航空对气候变化的影响。

4. 结论

4.1 航空环境保护委员会工作方案的各项要素与国际航空与气候变化组的各项活动密切相关，尤其是关于燃油消耗技术和运行目标的工作；环境目标评估；以及取代 303 号通告的新指南的工作，这些将分别有助于制定全球渴望实现的目标及减少排放的措施清单。重要的是，航空环境保护委员会和国际航空与气候变化组继续合作，以便最大限度地提高这方面的效率，并推动两个小组各项活动之间的协同。

5. 小组的行动

5.1 请小组：

d) 注意到本文件中的信息；和

e) 审议航空环境保护委员会在审议国际民航组织的行动方案方面，如何能够进一步支持国际航空与气候变化组的各项活动。

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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.

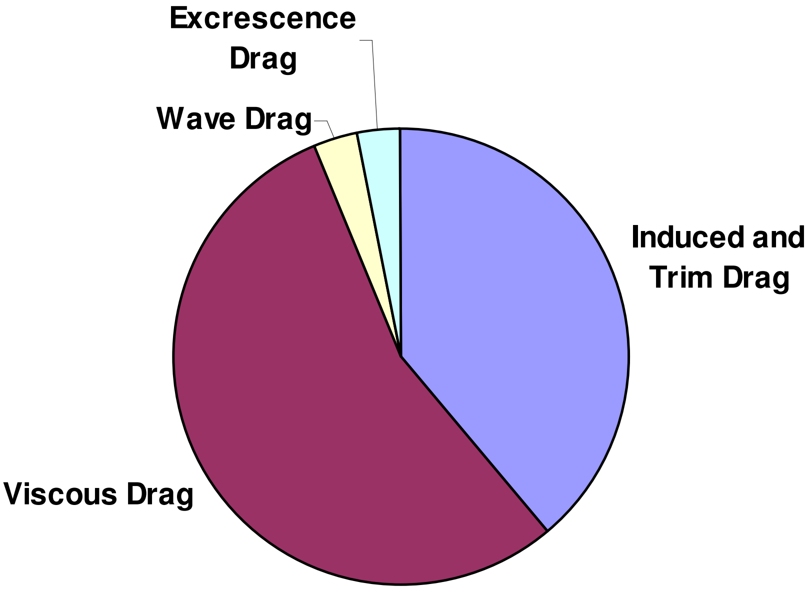

Figure 1 Typical Drag Breakdown for Subsonic Commercial Aircraft at Cruise Condition

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.

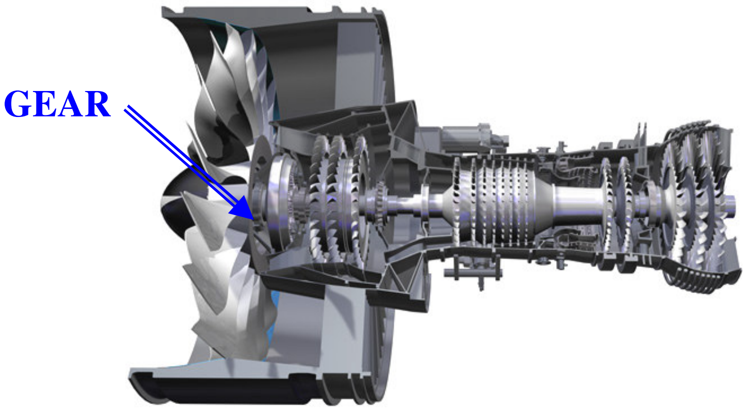

Figure 2 Typical GTF Cross-section

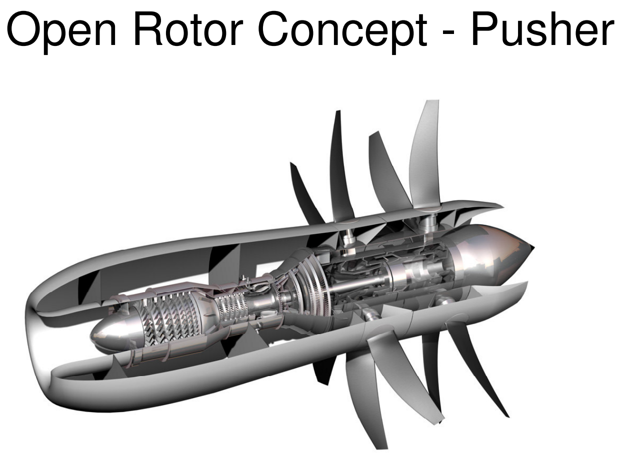

Figure 3 Typical Open Rotor Concept - Pusher

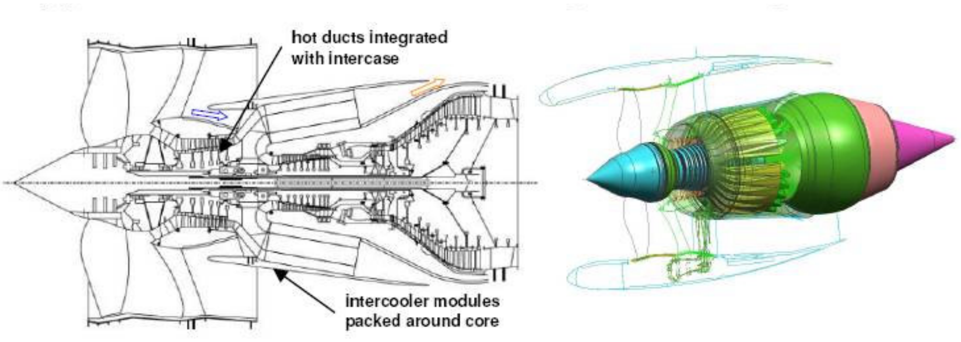

Figure 4 Possible Intercooler Aero Engine Configuration

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).

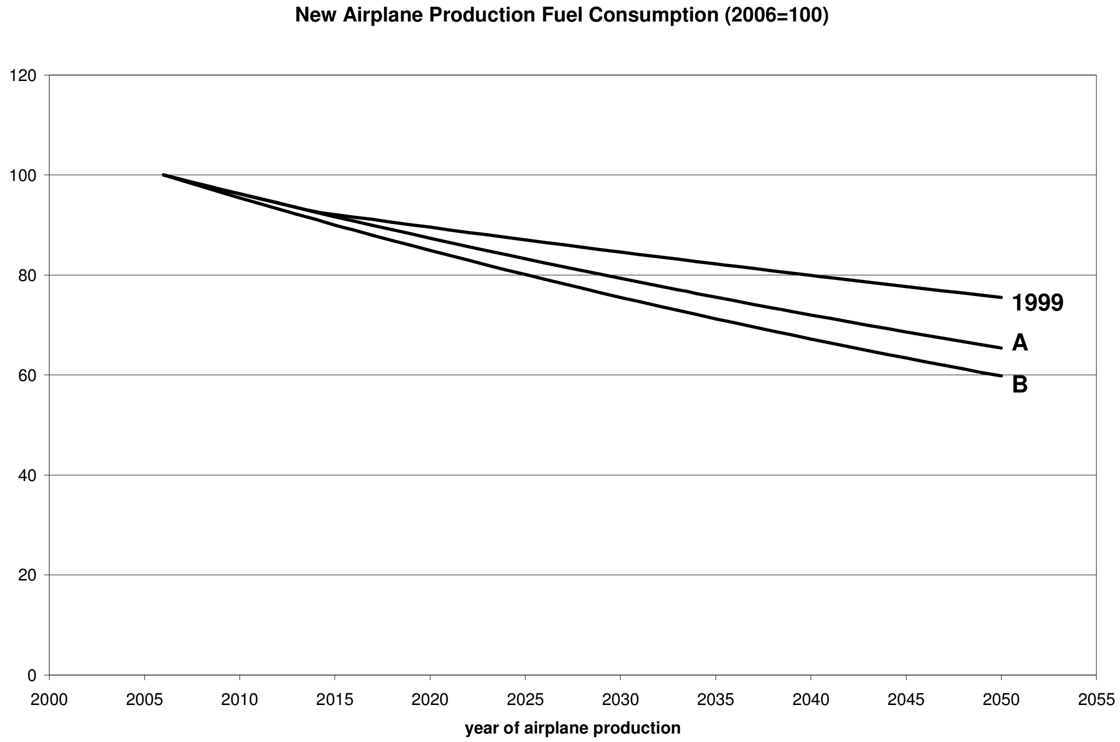

Figure 5 New Production Aircraft Fuel Consumption Scenarios

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.

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