KEY TECHNOLOGY ENABLERS FOR THE FUTURE OF AERONAUTICAL EQUIPMENT INDUSTRY

Alain Coutrot
SAFRAN, Vice President R&T

Abstract

Aeronautical Equipment Industry is living a significant (r)evolution: its shift from "build to print" to a "global intelligence" driven business makes it a major contributor in the innovations needed for sustaining the growth of the aeronautical transportation system. Those trends are analyzed, and illustrated by several achievements of the Aeronautical Equipment Branch of SAFRAN.

Introduction

Since a few year a new context has evolved for aeronautical equipment industry:

- future stakes for aeronautics ask for more innovation
- old style work organization where airframers used to design by themselves airframes and systems , buy equipment, and integrate them, is not favorable enough for innovation
- innovation implies sharing core issues and identifying together key factors of success through shared system analysis
- innovation requires that equipment industry shifts from "build to print" to a "global intelligence" driven business by considering final customer needs, operator (airlines, air traffic control organizations) needs, environment (airport, community) requirements, this means a better understanding of the global aeronautical system to propose high value innovative concepts, covering the whole scope of:
  i. New technologies
  ii. New functions
  iii. New architectures to generate functions

The future challenges of aeronautics

The commonly agreed challenges among the whole spectrum of stakeholders in Europe within the ACARE[1] are:

- quality and affordability: the goals relate on one side to the passenger value for money, on the other side to the supply chain efficiency, typically halving the time to market
- environment preservation: halving fuel consumption per pax.km, cutting NOx by 80%, reducing perceived external noise by 50%, and progress in reducing the impact of manufacturing, maintenance and disposal of aircraft
- safety: reduction of accident rate by 80% and consequently addressing the reduction of human error
- efficiency increase of the air transport system in terms of capability to accommodate three times more aircraft movements in 2020, to ensure on time flights, and to reduce time spent by passengers in airports
- security, the goal being zero successful attack or hijack.

All these challenges can be achieved only in the frame of a global system approach involving the aircraft, the airport and the air traffic management. They may be conflicting one another: therefore a series of compromises has been hypothesized within five High Level Target Concepts, each of them corresponding to a desirable prospective vision of Air Transportation System (ATS):

- Highly Time Efficient

[1] Advisory Council for Aeronautical Research in Europe

- Ultra Secure
- Highly Cost Efficient
- Highly Customer Oriented
- Ultra Green

The Aeronautical Equipment Industry has to contribute to the solidification of theses HLTC, by delivering proper innovation with the right balance between the conflicting challenges. As will be shown this requires a new innovation model in the companies.

Towards more shared system innovation

As may be seen through the recent story of Boeing 787 and its European competitor Airbus A350, to be successful a new aircraft must include innovation. Innovation is a process that produces value for the whole chain involved in the aircraft design , manufacturing and operation including the equipment designer and its suppliers, the system designer and the airframer, the airlines and the passengers. Such an objective is really difficult to achieve when each stakeholder keeps working alone: traditional business organization with airframers or systems designers defining their concept from market needs, then splitting them into a hierarchical series of procurement specifications, proceeding with integration through numerous reviews, design change requirements and compromising performances with waivers cannot be really innovation efficient. Moreover the control of technologies within a single big airframer company is no longer possible nor affordable: technologies are no longer specifically developed by aeronautical industry for aeronautical applications, they come from other domains, such as ICT[2] or electronic component industry for which aeronautics is a minor user compared to the broad spectrum of communication or automotive industries. Competition among the airframer and system companies has grown dramatically: consequently those companies need to concentrate their capabilities on critical technologies, outsource the remaining ones and team with others to stay on the leading edge of the technology panel.

On the aeronautical equipment side the business has evolved similarly to answer the innovation paradigm: the equipment industries shift from “build to print” to “global intelligence” driven business that considers the final customer needs, the operator (airlines, air traffic control organizations) ones, and the environment (airport, community) requirements. Both airframers and equipment industries need to share issues at the highest level of the transportation system and to identify together the key factors of success through system analysis.

Aeronautical transport system drivers

It is possible to summarize the drivers for designing an aircraft system or component in terms of flight capabilities, cost efficiency, environment friendliness and security:

- Security

This later will be considered only partially in this paper, although it is at the top of debates. Security issues for aerial transportation are far wider than their impact on the aircraft itself or even on the airport: they encompass the overall security system of states, borders, info-sphere and so on, therefore the needed analysis to identify the desirable high value innovations are much broader than those described in the present paper that will deal with the aircraft only. As a matter of example protection of aircraft against MANPADS[3] is a topic to be addressed.

- Flight capabilities

Making the flight itself to be easier, simpler, safer, and s.o. remains the very nature of our business. This goal has not changed fundamentally since the pioneers of the last century.

i. On board energy savings may be considered as the key of the more

[2] Information & communication technologies

[3] Man portable aircraft defense system

efficient flight: the sole energy source being the on-board fuel, any saving translates immediately into weight saving, into additional payload. Concurrently on-board energy consumption tends to increase dramatically, mainly driven by directly sensible for the passenger requirements such as multimedia entertainment, more comfortable seats, better air conditioning,….

ii. Weight savings have always been a must: airframe weight reduction is still a driver for new composite materials and process development. Equipment industries although rarely being at the front end of those developments, have to make efforts for transferring the latest advances in that field into their products.

iii. Autonomy is a new requirement that is linked to the increase of traffic. The issues of ATM call for more autonomy in-flight as well as during taxiing in order to reduce the burden on men, in the cockpit as well as in the control rooms. Smart aircraft will help in safely densifying the traffic: this translates into integrated communications, sensor data fusion, enhanced synthetic vision,…

- Cost efficiency

Aeronautics, at least commercial aviation, has become a global business, and is ruled by competition: the difficult life of airlines faced to fuel cost increase and enhanced security constraints put more pressure on aeronautical industries. Cost efficiency is searched on the whole cycle of aircraft:

i. Design cost efficiency is not just a matter of powerful CAD: assessing system performances requires multidisciplinary design and optimization techniques, and reliability and robustness of modeling calls for a better understanding of multi-scale physics

ii. Manufacturing cost reduction has been pursued for long through automation. Other ways are being developed, in particular modeling the processes and the plant, so that production set up may be done in a more efficient way.

iii. Operation and maintenance are mainly determined by initial design; but they can be put under more efficient control with the use of monitoring systems that give access to customized usage trends, facilitate maintenance planning and allow on condition maintenance.

- Environment friendliness

That topic must be considered broadly considering all the impacts of the aeronautics onto the life of men, among the public, the passengers and the workers, submitted to the effects of the aircraft in the various phases of their use, from production to disposal.

i. Community friendliness is the most sensible topic as the impacts of aircraft operations concern numerous people not directly benefiting of any return from its services. Although airframers and engine companies are at the front of those issues, equipment industries involved in airframe components need to participate to the noise reduction technology development and to the design compromises.

ii. Passengers are surely the first to be cared at: their health and comfort are drivers of quite a few innovations, for example in the field of air conditioning.

iii. Industry and operator work conditions have become subject to regulation for long: for instance use of most of chloride based solvents have been forbidden, and additional chemical species such as lead, chromium 6+, cadmium are under a ban process in the European Union and several other countries. Moreover industrial companies are pushed by markets to anticipate these bans, especially in aeronautical products as their life cycle may be as long as 30 years.

Innovation thrusts and facts at SAFRAN

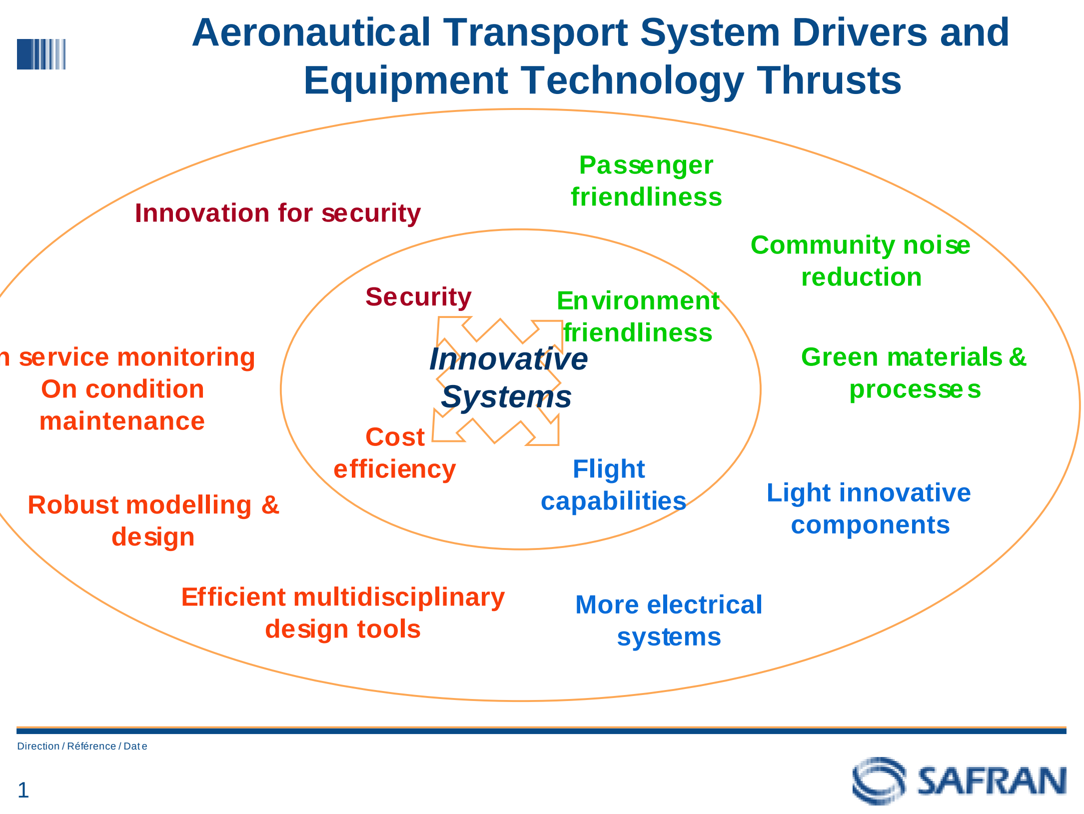
Starting from the previous analysis SAFRAN Aeronautical Equipments has developed an innovation strategy in line with the four drivers, flight capability enhancement, cost efficiency, environment friendliness, and security, combined into a system optimization. That strategy has been implemented in those nine thrusts:

- light innovative components
- more electrical systems
- passenger friendliness
- community noise reduction
- "green" materials and processes
- efficient multidisciplinary design
- robust modeling
- in service monitoring
- systems for security

• Light innovative components

Leveraging new materials and manufacturing technology from other products generally can achieve lighter components. Within SAFRAN innovative technologies have been developed primarily for engine applications: those last years the enforcement of synergies among the various companies of the group has allowed significant innovations in different fields:

- interlocked carbon fibber RTM composites developed for the very demanding requirements of fan blades, specially in terms of impact resistance, are being used to manufacture landing gear braces. A few tens of kg. can be saved on a large aircraft LG thanks to their high mechanical properties, and excellent robustness to the potential foreign object projection from the tarmac is expected.



- another example of light component is that of Ceramic Composite Materials that have been developed for space re-entry, that have been extensively tested on military engine nozzle flaps, and that are now proposed for turbofan primary exhaust systems: the big challenge for those civil commercial applications is the life expectation that has to be as long as for conventional alloys. Thanks to a self-healing matrix, that reacts with oxygen and fills the micro-cracks with the oxidation products (i.e. several grades of glass according the temperature), the component can be proposed as part of an advanced nacelle, with a weight saving of 35% versus conventional nickel alloys, meaning one more passenger on a long range aircraft.
- apart from composites, progress have been made for instance on aluminum alloys for wheels: better properties at high temperatures allow a better optimized wheel and brake design with significantly less carbon-carbon for the brake heat sink.
- structural components are not the only area where to save weight: a promising way is based on innovations on electrical wiring. New materials as aluminum for cable wires have been used on A380, new technologies as wi-fi or Power Line Communication for data transmission are being evaluated.

- More electrical systems

The More Electrical Aircraft (MEA) is one of the most significant technology change for the next future. Aircraft as other transportation platforms such as ships, cars, and trains is unifying its energy transport media with electricity. The benefits that are expected are cost reduction, more flexibility and availability from easier reconfiguration capability, and less fire hazard from hydraulics ban.

Maintenance cost reduction will be probably the most significant benefit, through several ways:

- On an electrical device monitoring of performances and defect localization is straightforward, no additional sensors and little human action are required to get useful data.
- Human maintenance actions will be less frequent than on an hydraulic system (no more fluid leakage, increased capability to operate on degraded modes,….)
- When human maintenance actions will take place, they will be much easier, thanks to a better modularity of LRU.
- The overall aircraft systems development cost will benefit from the unification of energy transport media unification : the airframer job in optimizing and managing one kind of energy in the A/C will be simplified, hydraulic and pneumatic tubing will be suppressed, thus the installation will become easier. Moreover electrical systems offer more flexibility for customizing and upgrading
- Of course the counterpart could be the higher cost of power electronics compared to those of mature hydraulic components, but in the future standardization and modularity, together with generalization of electrical systems will push the costs down.

Performance trade-off is favorable to more electrical systems thanks to their easier reconfiguration capabilities : thus the peak-installed power can be reduced typically by 25%, and the mean power consumption by 15%. Such a benefit is valuable as commercial electrical loads (multimedia services for the passengers, smart seats,…) are increasing drastically, and can be translated into fuel savings .

Electrical systems are already invading new aircraft. For Airbus A380 , A400M European military transport A/C and Boeing 787 Dreamliner, SAFRAN has developed some of the first electrically actuated systems on large commercial aircraft:

- The ETRAS® thrust reverser of A380 developed by Aircelle and Hispano Suiza
- An hybrid Electro-Mechanical Back up Hydraulic Actuator developed by

Messier Bugatti for the A400M main landing gear door
- Electrically actuated brakes developed by Messier Bugatti for the 787

More work is under way to design broader electrical systems, such as a complete electrically actuated landing gear, or electromechanical flight controls. These examples are mostly direct transpositions of previously hydraulic or pneumatic equipment or unified systems to electrical actuation. Such a transposition cannot represent an actual optimum as generally such a pin-to-pin substitution gives a weight increase. The way to the truly optimized MEA, or even to the All Electrical Aircraft, is through an overall system redesign, including a trans-ATA approach: for instance a shared power electronics package could be proposed for both landing gear actuation and secondary flight controls, as they require similar power, are located close one to another, and are used sequentially.

The other condition for going more electrical is to offer improved technology and more robust architecture for power electronics, actuation and drive systems. SAFRAN has settled two years ago SPEC[4], a dedicated corporate organization and program, backed by a network of fifteen academic laboratories to make progress in the following fields:
- Power network quality, EMI control
- Technologies for harsh environment electronics
- Power converter design and advanced packaging
- System architecture

- Passenger and community friendliness

For passenger comfort a lot must be done to insure high cleanliness cabin air: SAFRAN in its subsidiary Sofrance has currently developments aiming at removing particles, odor, VOC[5] and bacteria : one of the challenges for these new devices is to be interchangeable with current filters.

Community noise reduction has become also a requirement for landing gear designers: companies like Messier Dowty have to add acoustic modeling expertise to the more traditional mechanical engineering capabilities. Flight demonstration with noise reduction devices fitted on a A340 landing gear has been recently performed in the frame of the UE SILENCE(R) program.

- Green materials and processes

Protection of worker's health and manufacturing environmental impacts are two drivers for regulations on toxic materials and processes. Aeronautics being a global business the most stringent regulation among all countries becomes the driver for the market: final customers want to be sure of acquiring equipment that is environmentally friendly, with as low as possible toxicity for people.

For instance the substitution of hexavalent chromium in a lot of processes is a main challenge. The first substitute developed a few years ago is a WC-Co-Cr type HVOF sprayed coating. This protection has been applied on the A380 nose landing gear: it has required extensive work to control diamond grinding, to develop hardwearing seal elements as well as to set up a corrosion resistance data base including fatigue and friction testing. However, this technology only gives a partial answer to a complex set of problems that include obtaining a thin coating, manufacturing parts from non compatible materials with that deposit temperature, applying coating to small diameter parts or parts with deep bores or with complex-shaped surfaces, and s.o. To address these issues the qualification of a wet processes "UltraCem™" has been started with UCT Coatings by Messier Bugatti. Extensive characterization in terms of hardness, abrasion resistance, hydrogen embrittlement, corrosion resistance,

[4] SAFRAN Power Electronics Center
[5] Volatile Organic Components

adherence, fatigue life reduction effects and tribological properties is needed yet.
Another path to get rid of toxic surface treatments is to develop corrosion free high strength steels: in that area 1700MPa Grades have been qualified and will be used on A400M and 787 landing gear structures, and development are underway to raise strength up to 1900MPa.

- Efficient multidisciplinary design

The requirement for halving the time to market translates into efficient multidisciplinary design tools in every aeronautical equipment company. Here are two examples within SAFRAN:

- landing gear design requires modeling capabilities at several levels:
  - aircraft landing and ground maneuvers simulation, and corresponding dynamics,
  - full landing gear and individual component structural analysis (static, dynamic, fatigue),
  - tires, shock absorbers, links, seals and actuation devices simulation,
  - various physical modeling like aeroacoustics .

  All these models are managed within a hierarchical architecture that allows optimization, quick data access and reduction .
- the aircraft wiring design process has been organized into a smart tool interconnecting automatically block diagrams, functional system schematic, wiring diagrams, with a bridge to the manufacturing data management system and to the physical installation modeling on CATIA.

- Robust modeling

Efficient design tools well organized within a chained friendly architecture are not enough: the modeling must represent the complex physics of some critical components, for instance:

- dynamic seals of shock absorbers are subjected to complex stresses and behave differently according to their visco-elasto-plastic properties and their variation with age, their installation in the piston and the pressure distribution during the shock absorber compression and extension strokes. Only a fair understanding of those phenomenon allows a long predictable in service life, with large benefits on maintenance costs: a program is still underway for that purpose.
- a still more challenging knowledge is that of the physics of carbon brake friction. One can say that braking is at the centre of four sciences: mechanical engineering, thermal modeling, dynamic simulation and tribology. To deal with the multiscale physics in carbon tribology, basic material science capabilities have been developed for nearly twenty years at LCTS, a dedicated joint laboratory of SAFRAN, CEA, CNRS, Bordeaux University for carbon and ceramics composites. This science investment has allowed the constant improvement of brake friction materials in terms of performances but also in terms of cost per landing.

- In service monitoring

In service monitoring is a concept that was first implemented for safety purpose: for instance the Tire Pressure Monitoring Systems of Messier Bugatti is used on some 2000 aircraft: that equipment is being upgraded by implementing wireless data transmission, that will make it more maintenance-friendly as frequent wheel removals are needed for tire change.

Adding intelligence, and monitoring more complex systems can bring value to the operator. For instance on landing gears knowledge of ‘real-world’ component usage allows:

- better fatigue spectra for design purposes
- more accurate prediction of component life
- anticipation of necessary redesign

Knowledge of individual component condition allows:

- identification of operation beyond design conditions (i.e. overload)
- early detection of damaged parts
- reduce maintenance burden and decrease aircraft turn-around time
- possibility for ‘on-condition maintenance’ and ‘lease-a-landing’

Knowledge of shock absorber servicing status allows:

- reduction of manual checks and unnecessary servicing
- reduction in mis-servicing related problems

Transducer technology, data treatment and transmission are being developed for such a monitoring system and tested on a few commercial aircraft.

- Systems for security

One of the challenge is the protection of commercial aircraft against MANPAD missile terrorist attacks: as a few ten thousands of these weapons are disseminated across uncontrolled organizations, that threat is considered as actual, and specific deception systems have to be designed since military Infra-Red Counter Measures (IRCM) systems cannot be straightforwardly installed on commercial aircraft for several reason: weight , cost, collateral effects in a civil environment. The process of defeating an IR missile includes two necessary tasks, detecting missile launch, and executing countermeasures to defeat the missile guidance system. Modern IRCM systems rely on sensors mounted on the protected aircraft and either infrared decoys (flares) or directed energy laser systems to blur the missile IR seeker : the fire risks from the first makes them unacceptable, the second must be tailored to the specific nature of threat and affordable in terms of mass and costs. For that goal CASAM[6] a FP6 program under the lead of Sagem Défence Sécurité has been initiated this year.

[6] Civil Aircraft Security Against MANPADS

Summary

In summary let’s recall a few key success factors for delivering efficiently the innovation that will benefit to the future air transport system and be a driver of aeronautical equipment business.

The first condition for success is the alignment of the R&T road maps with the drivers of future ATS: this implies an in-depth analysis that may be a new practice for equipment companies, more used to straightforward technology development based on the “old” or “previous aircraft” specifications. That new “ intelligence” can be more easily gained through partnerships first with airframers, then with technology providers, academics and scientists, as well as with other industries that may be confronted to similar innovation push in their field. Airframers for various reasons find interest in partnering in technology prospective and demonstration, and are offering participation in their demonstration programs, like the QTDs[7] of Boeing, and hopefully the CLEAN SKY Joint Technology Initiative under preparation in the European FP7. The other industries with which SAFRAN has cooperation on basic technology are transport and energy that are both interested in fielding power electronics systems. Aeronautical equipment companies are also very active in the Research European Framework Programs: for instance SAFRAN companies have a significant participation in three large technology platforms, POA[8], SILENCE(R), and TATEM[9], by the way all three being under the leadership of an equipment company. All this clearly shows that aeronautical equipment industry has become a major player in innovation that is key in the ATS development.

[7] Quiet Technology Demonstration
[8] Power Optimized Aircraft
[9] Technologies And Techniques for New Maintenance Concepts