



## The challenge of Quality & Affordability



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# Executive Summary

This report represents the results of the time bounded study into the 'Quality and Affordability' and to the establishment of the first release of the Strategic Research Agenda. 'Quality and Affordability' refers to the Challenge of delivering passengers, freight and other customers the increasing quality, economy and performance for sustained international competitive success.

Four major Goals have been identified as main drivers of research in this area:

- Reducing travel charges
- Increasing passenger choice
- Transforming air-freight services
- Creating a competitive supply chain able to halve-time-to-market

The baseline adopted for the Goals is the latest existing European products being currently delivered and the external scenario considered is the one underlying Vision 2020. The approach has been to focus on describing the 'evolutionary' routes from the technical and operational approaches identified to achieve the different components of the individual Goals to the Goals themselves. Some of the 'revolutionary' but unproven developments in technology now emerging have also been mentioned. A substantial amount of work has been initiated to identify the corresponding detailed technology targets and technology requirements.

## Reducing travel charges:

*Main drivers in this area are: the cost of aircraft ownership and maintenance, the cost of fuel, the cost of cockpit and cabin crew and ground personnel as well as the costs of operating charges including fees and insurance.*

Each of these can be improved with the application of new technology in various fields like product design, product development and manufacturing processes, simulation, certification, architectures, maintainability, automation, etc.

## Increasing passenger choice:

*Passenger choice embraces five areas of research: travel costs (addressed above), time to destination, specific services, human needs, general comfort.*

Time to destination greatly depends on issues addressed in the Challenge of Efficiency of the Air Transport System. Vertical Take Off and Landing (VTOL) as well as low/high supersonic or even hypersonic aircraft studies and the development of corresponding technologies will continue and be directed towards optimising the balance of aircraft and operating characteristics.

Passenger services will be greatly extended and will have to be consistent with the fast development of communication and multimedia capabilities. Research will also lead to effective means of protecting health and comfort economically.

## Transforming air freight:

*The research planned to reduce passenger travel charges will be applicable to freighter aircraft. Tremendous additional benefits are also expected from the research on increased automation, specific freighter configurations, improved intermodal compatibility and reduced operational constraints*

## Creating a competitive supply chain able to halve time-to-market:

*Research needs have been identified in the following main directions: supply chain integration, systems engineering, design for life cycle value.*

Huge opportunities exist for integrating the supply chain into the earlier innovative stages and in the continued adaptation of the product through for example improving the dynamics of the supply chain, integrating product definitions, increasing knowledge propagation speed, developing new architectures.

Systems engineering is the holistic approach to creating competitive product and includes methods, tools, processes and working procedures. In order to develop new Systems Engineering extensive research will have to be conducted in various areas like for example, improved flexibility and adaptability, better modelling and simulation, renewed certification methodologies.

Research for Design for life-cycle value will aim at developing tools and processes allowing a better implementation of new functionalities in new and existing aircraft with much less lead time.

The main global conclusions of the work undertaken are as follows:

- Responding to the increasing demand of passenger and freight air transport services as well as to social pressure on safety, security and environment will require Solutions that provides ambitious and balanced characteristics.
- Some of these Solutions will need to be novel in concept even if the introduction of these novel concepts must be preceded by the introduction of intermediate changes in products and operating systems within the air transport system. Intermediate steps like one man cockpit aircraft, pure freight aircraft tilt-rotor could be achieved by 2010 while new global concepts like Supersonic business jets, pure freight, fully automated aircraft, hybrid type freighter are contemplated at the 2020 horizon.
- The transition to a future system providing excellent quality and affordability will depend upon the technological, operational, regulatory, certification and social acceptance aspects addressed in the SRA.
- Achieving the ambitious goals will require the promotion of a number of actions with respect to the research community: limit fragmentation / increase harmonization between structures, foster long term high risk research, promote transfer of basic research to applied research, etc.

# Introduction

This document represents the output of the investigation into the challenge of quality and affordability undertaken during the period from September 2001 to March 2002 as an input to the October 2002 issue (Release 1) of the Strategic Research Agenda (SRA).

In trying to identify the fields of technology where improvement is needed and achievable, the Vision 2020 imperatives have been addressed as a starting point to meet the societal needs and winning global leadership. The focus is on the improvement of products leading to better services for the end user of air transport (fall in travel charges, wider passenger choice, air freight services), and improvement of the European aeronautical industry competitiveness (reducing time to market & competitiveness of the supply chain).

Taking forward the Quality and Affordability recommendations, drivers and Goals contained in Vision 2020, we derive more detailed research objectives and the Contributors by which we will realise the Vision. During this period more than 35 individuals have participated or have been associated with the activity and the group represents a fairly well balanced participation of the various stakeholders and of the different product families.

In defining the scope of our work, the group took notice of the parallel work of the investigations into the other ACARE Challenges. Equally, it was recognised the market for major sub-systems as products in their own right, as well as components of European aircraft. Prime examples include engines and avionics. However, in taking mainly an aircraft based approach (large airplane, regional, business jets, rotorcraft etc.) for this first phase of ACARE, most of the aspects for these sub-systems have been covered.

This challenge, of Affordability and Quality, is one of high interdependence with other areas. For example, the way in which an aircraft is used (ATM) will interact with affordability, as will developments in propulsion.

The approach has been to focus on / develop the 'evolutionary' route to the objectives but also to accommodate some of the 'revolutionary' but unproven developments in technology now emerging. Other future developments, whilst as yet difficult to predict, must also be capable of being encompassed by the SRA.

Indeed, as mentioned in Volume 1, there are signs that European Aeronautics may be at the beginning of another 'S-Curve' which is the usual way to illustrate the evolution with time of the status (eg. emergence of a new concept, maturation of technology and processes, development etc.) of any industrial product or activity (e.g. traffic growth of large fixed-wing aircraft). So it is vital that the SRA is capable of addressing this possibility. Continued funding of high-risk basic research in the universities and Research Establishments together with a suitable set of enabling measures is thus essential. It is anticipated that the second release of the SRA will include far more with respect to strategic enablers such as education and research establishments.

The methodology adopted was essentially to commence with a matrix of 'Goals – Enablers – Capabilities', which was later converted into a 'Goals – Sub-goals – Solutions – Technologies' and finally displayed using a pre-defined graphical template. The scope adopted was 'kerb-to-kerb', including all aspects of loading and unloading, aircraft utilisation, flight routing, etc. Key airport operational elements from the challenge of Air Transport System efficiency were naturally vital contributors in their own right to meeting this challenge. Equally, all aspects of the design, development and manufacturing supply chain and certification / operation including product support have been considered.

# Background

Quality and affordability of the products delivered by the European industry must be maintained at a level responding to the increasingly exigent end user, the market (air transport system), the regulation and to the competition. This can be achieved only through a continuous exploitation of newly developed technologies.

All sectors of the industry (Aircraft, Engines, Equipment) are competing in a global market. In all these areas, Europe has developed competitive products, often through the rapid introduction of new technologies.

There are several areas in which Europe currently has an advantage; but, when taken overall, European civil aeronautics technology level is essentially similar to US technology level. We are thus not beginning from a position of significant advantage, nor of disadvantage, however, considering the economic power and market penetration of main competitors Europe must continue to innovate aggressively to achieve advantages or at least to retain its position.

When comparing the situation in Europe with that on the US scene, the first major difference seen is the greater separation between Defence and Civil research activities in the EU. This can, and does, lead to less visibility of military developments and more difficult technology transfer.

We must also recognise that the more fragmented nature of Europe's support for civil Research and Technology (R&T) has led to less support for larger innovative aeronautics concepts and for risk-reducing technology verification and proving.

This lack of support can delay the transfer of creative science from the University laboratory into innovative use on the production floor. It is in these areas that Vision 2020 rightly calls for changes and improvements, leading to enhanced efficiency and effectiveness. The Strategic Research Agenda is an important tool to concentrate our efforts to this end.

The SRA thus will base its strategic consideration on the Vision 2020. The emerging operational plan, going into much deeper details of technology descriptions will have its foundation in documents like ARTE 21.

The reports mentioned below were used as background sources in the process of generating this report:

- IPCC (environmental impact of aviation)
- ARTE 21 documents (industry position on technology needs)
- 'Greener by Design' (The Aeronautical Journal)
- 'Aeronautics for Europe' (Position Paper of the External Advisory Group for Aeronautics to the European Commission)
- NASA Blueprint & White Paper

# Challenges and goals

## Survey of Vision 2020 goals and Goals primarily considered

Vision 2020 identified twenty-five Goals in total and it was recommended to consider one supplementary goal 'Airport Capacity' in addition to 'Security' which was included as a specific fifth Challenge by the ACARE.

Five of these 26 Goals explicitly relate to the "Quality and Affordability" Challenge, while two others identified in the fifth Challenge 'Securing European Global Leadership' are in close relation with the scope of the "Quality and Affordability" Challenge. Consequently, it was decided to concentrate on the following set of Goals :

**Fall in travel charges:** A steady continuous fall in travel charges through substantial cuts in operating costs.

**Passenger choice:** The same choice of facilities that are available on other forms of transport including leg room, flexible seating and office facilities incorporating state of the art communications. A greater choice of flights from regional locations.

**Air-freight services:** A larger percentage (by value) of cargo travels by air because it is more competitive with land and sea transport and it is fully integrated into a seamless intermodal freight transport system<sup>(1)</sup>.

**Supply chains:** A new framework that permits and encourages companies to work together more effectively in setting and achieving their industrial priorities. This will strengthen competitiveness and improve response to changing market conditions.

**Halve time to market:** Halve the "time to market" for new products with the help of advanced electronic analytical, design, manufacturing and maintenance tools, methods and processes<sup>(2)</sup>.

In addition to the detailed description of the Contributors primarily considered to meet the challenge (which basically refer to 'products' and related processes) and shown in **Figure 01**, the report provides some additional inputs to the other Vision 2020 goals, especially for those which are closely linked to 'Quality and Affordability' aspects.

## Assumptions and hypotheses adopted

### Baseline adopted for the goals

The proposed baseline for the investigation into the challenge was defined as all items needing quantification (in terms of : payload, range, speed, environmental criteria, etc ) and which are 'current production standards', i.e. latest existing European products being currently delivered. By doing so, a general reference rather than always debatable exact figures is provided.

- Fixed wing aircraft :
  - Large : A340-300
  - Medium : A320-family
  - Business : Falcon 2000
  - Regional : SAAB 2000, Dornier 328 jet
- Rotorcraft :
  - Light : A109E, EC135
  - Medium : AB139, EC155
  - Large : EH101, EC225

### Objectives and scenario

As far as the goals are considered they have to be seen either as objectives in terms of 'technology readiness' at that date or actions to be absolutely launched by 2020 in order to secure competitiveness after year 2020. At this stage it might also be kept in mind that the effect of new products available in 2020 will propagate as the rate these new product are introduced on the market.

In the frame of release 1 of the SRA, the external scenario used is the one underlying Vision 2020.

Interactions with the goals of other challenges have been taken into account in the best possible way although it should be kept in mind that a thorough review of the interactions will need to be undertaken for the second SRA release.

(1) Other aspects like the public utilisation of Rotorcraft and of Business Jets (medical evacuation, etc..) which are not explicitly considered in Vision 2020 will benefit from research activities in this field.

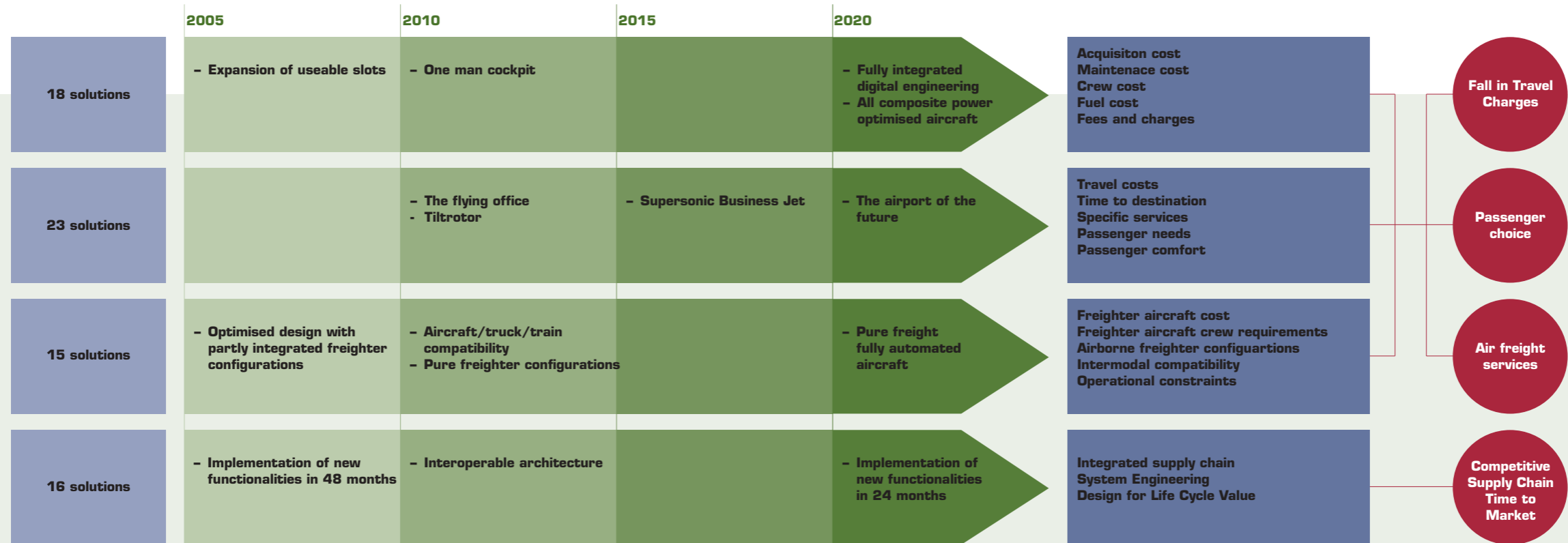
(2) The other issue 'Time to delivery' not explicitly considered as a specific goal is however addressed in "Competitive supply chains and halve time to market" on page 47.

### Comments on the way to present results

In order to more easily identify and analyse interactions between the various considered items (i.e. Goals, Solutions, Technologies) it was decided to utilise a common graphical representation. In order to do so, the following definitions were established

- **“Goals”**: the challenging, quantified targets as laid out in the “Vision 2020”, revalidated, reconfirmed and if necessary supplemented. Note that, in the present document, goals identified in “Vision 2020” have been numbered by “page number. Order number on page”. Hence goal “16.3” is 3rd goal on page 16 of “Vision 2020”.
- The main research routes to reach the Goals mentioned above are named **Contributors**. These Contributors themselves are realised through a number of parallel or serial **Solutions** throughout the SRA timeframe.
- **“Technology targets”** represent major steps in the logical progression over time for each of the Contributors e.g.: “Advanced materials and structures concepts”
- **“Technology capabilities”** represent compulsory needs to achieve each technology target. They are expressed as technical domains in which excellence will provide competitive advantage for products but which cannot be illustrated by graphical representations for clarity purposes. e.g.: “Composite technology”.

Figure 1  
Schematic overview of the Contributors and Solutions to meet the Challenge of Quality and Affordability



# Contributors

## Fall in travel charges

To prepare the ground for product based continuously and substantially falling travel charges, the focus of technological improvements has to be placed on those elements and processes which represent the significant cost drivers in the major areas of the operating cost, as figure 2 shows these cost areas are those of :

- aircraft (vehicle) cost
- maintenance cost
- crew cost
- fuel cost
- fees / charges

Due to the tremendous competition between the airlines resulting in shrinking margins over the last years, the technologies to be developed identified for the achievement of this goal have to trigger a quantum step in cost reduction in all areas mentioned above to prepare take economic basis for the owner / operator which will enable them to adjust the travel charges accordingly. For strategic considerations it should be noted that over a time span of 20 years the contribution of each of the costs areas can vary significantly (e.g. fuel cost with environmental taxes possibly added).

Operational based travel charges with an impact on product design e.g. :

- Dispatch reliability
- Turn around time
- Daily utilization

### Aircraft non recurring and recurring cost

Special focus in this area has to be placed on one hand on the **product development & manufacturing processes** and the optimisation of methods and tools as well as system integration technology and on the other hand on the building blocks of the product itself.

Reduction of design, testing and manufacturing cost will be achieved by progressing in the fields of e.g. knowledge based engineering, distributed concurrent engineering, computer aided manufacturing etc. (see also Goal 15.1/4) – information technology and process automation acting as enablers of significant efficiency improvements. Furthermore for a major period of the development process the product will stay a virtual one, reducing hardware requirements and allowing quick adjustments and changes as a reaction to changing customer needs.

**Automatic manufacturing system**, e.g. in the field of automated fibre placement systems and automatic assembly systems with a high utilisation of robotics, will be needed for all steps of the manufacturing process to reach the cost reduction objectives. The integrated design & manufacturing process and its methods and tools will support significantly Goals 15.1/4 to be achieved.

In future we will rely on **simulation** and digital product representation in almost every area. Certification as a major enabler to the vehicle cost will be – not exclusively, but to a significant extent – based on digital mock-ups, results from simulation and validation techniques using virtual product representation for system integration demonstration.

With respect to the building blocks of the product the reduction of number of parts will play an important role – reduction on one hand due to advanced design and manufacturing and on the other hand due to multifunctional, “smart” materials integrating insulation, acoustic, vibration, ducting functions into one structural component. In addition a special focus will be placed on sustainable performance characteristics of the product – the design for life cycle value is an important factor in any evaluation of aircraft cost.

### Maintenance cost

Today Built In Test (BIT) is a well-known feature in almost every electronic component. To use the component BIT on subsystem / system level in an intelligent, multi-parameter fault detection system will reduce the false alarm rates and unjustified removals with a direct impact on maintenance cost (and also dispatch reliability). System level BIT will allow the BIT coverage to be expanded in short term with a higher confidence level, furthermore it will support the expansion of BIT into the field of mechanical systems which today are not covered and normally require expensive ground test equipment.

In a long term perspective technology development will lead to remarkable failure tolerance and automatic reconfiguration characteristics ("self-healing") for all types of systems. This detection and reconfiguration capability will be part of an overall integrated health and usage monitoring (diagnostic + prognostic) and fatigue life monitoring system. Furthermore technologies for enhanced damage tolerance especially in the rotorcraft area need to be developed based on advanced component design as well as advanced material characteristics. Identifiable technology trends in the area of fault and damage tolerance are microsystems, nanotechnology also at macro-scale level, self-healing materials.

On board system improvements have to be accompanied by improvements in the ground segment as well to minimize the failures and damages induced by humans. Computer based maintenance support & training methods, IT assisted tools, i.e. Virtual Reality (VR) for enhanced maintenance support, will play an important role in cost reduction.

The onboard system elements as well as the ground based elements will contribute to the Goals 15.1/4 in the area of sustainable architectures.

### Crew cost

From the vehicle point of view crew cost reduction will have to focus on the two contributing onboard elements, the cockpit crew and the passenger cabin crew. Ground crew requirements are covered by technologies for the reduction of maintenance cost.

The key objective for technologies to be developed in this area is workload / training / airline average crew number per aircraft reduction, which will be achieved mainly through automation of routine tasks, with respect to flying and interfacing with the air traffic management system and passenger servicing as well. As crew cost reduction must also positively impact on safety and comfort, it will follow a stepped approach to built up the confidence required for acceptance of the measures selected.

The technology avenue will start from cockpit & cabin standardisation and **cross crew qualification** training, continuing with gradual automation of the flying task above the level of today's flight management and autopilot systems, flight path negotiation activities, system monitoring requirements etc., leading to long range crew requirement reduction and finally towards a single pilot cockpit. The cabin crew will be supported by a variety of automated cabin systems like automated catering, announcement systems and a cabin design allowing the individual passenger needs to be satisfied without crew interaction.

With respect to the flying task itself (more) automated collision avoidance systems, automated Air Traffic Management (ATM) interfaces, auto-start / land systems and automatic aircraft reconfiguration will pave the way towards the automation of the flight control system, changing the role of a passenger aircraft pilot into a supervisor role. Bizjets could be a first candidate for the application of the single pilot cockpit concept. Spin offs can be expected from the military technology developments in the area of Unmanned Airborne Vehicles (UAV).

Major blocking elements in this area are today's airworthiness regulations, legal and liability issues (component / aircraft manufacturer, airline, ground handling crew, Air Traffic Control (ATC) liability) as well as opposition to be expected from the trade unions fighting against any cuts in crew size.

Aside any legal aspect the crew cost reduction methods can only be implemented successfully if passenger acceptance is built up at the same ratio and speed as the automation process itself.

### Fuel cost

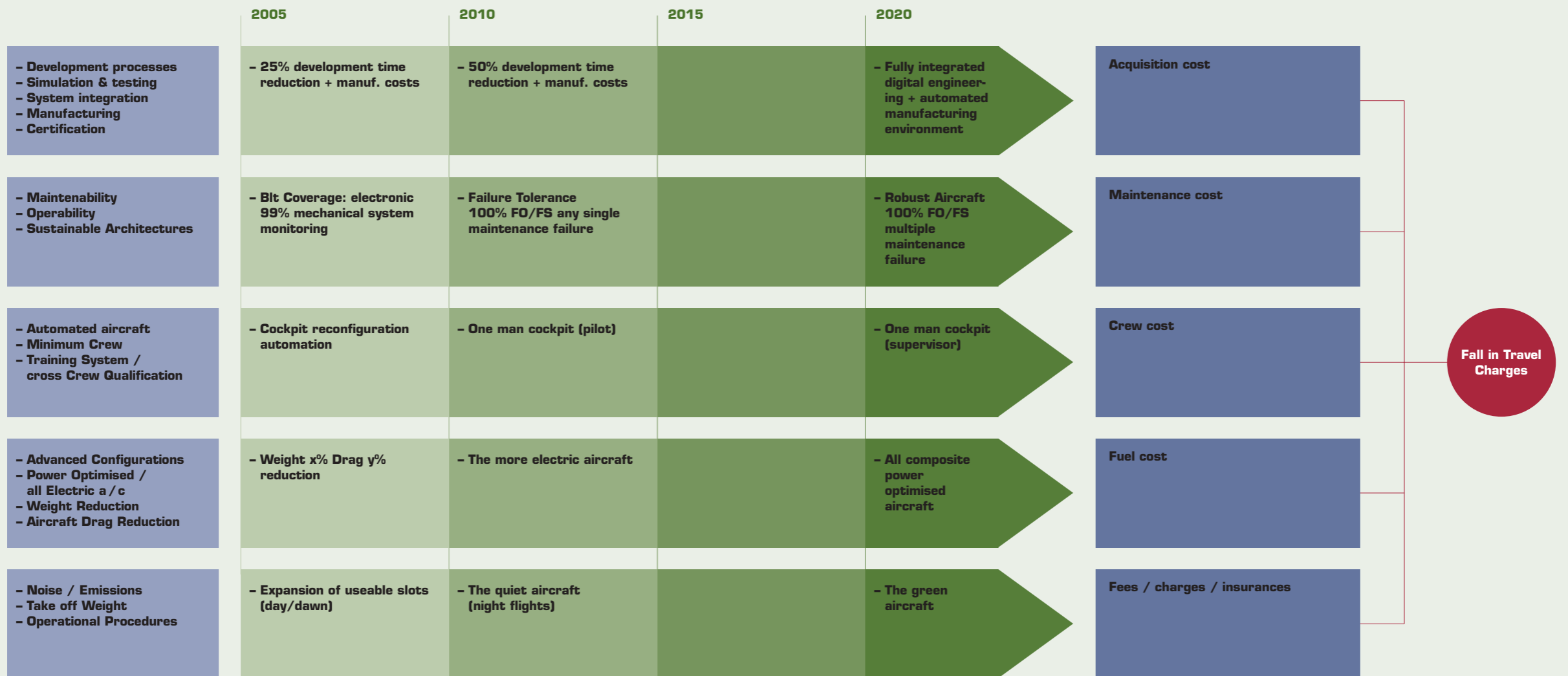
The technologies required for fuel cost reduction are the same as the one addressed by the environment challenge and are considered as an input into the technology portfolio for achieving the "fall in travel charges" goal.

Some technology trends in addition of those identified by the environment challenge should be monitored with respect to their maturity level such as emerging technologies like plasma boundary layers, micro-mechanical systems and propulsion independent power sources i.e. fuel cells.

### Fees / Charges

The technologies required for reduction of the fees / charges which are directly linked to the aircraft operation are already addressed by the challenges of the Environment and Air Transport System Efficiency respectively and are considered as an input into the technology portfolio for achieving the "fall in travel charges" goal.

Figure 2  
Schematic overview of the Contributors and Solutions to meet the Goal of fall in travel charges



## Passenger choice

The main Contributors to this Goal, as shown in Figure 3, are identified as:

- Travel costs
- Time to destination
- Specific services
- Human needs
- General comfort
- Health aspects

### Travel costs

While the main concern in the view of the passenger's wishes is a general and continued **fall in travel charges** (see Goal 13.3), another important aspect is the availability of different sets of offers, customized to the passenger's wishes far beyond what we observe today. The recent success of so called "no frills" airlines gives an example of the willingness of passengers to select between different levels of convenience in booking procedures and schedule, connections, comfort and on-board services. Each specific offer may have its own pricing scheme, which results in a wide spread range of ticket prices and a complex system of travel arrangements a customer can choose from.

While the general fall in cost for the operators is a prerequisite for the demanded fall in travel charges, lower cost for the airline also gives space for an airline specific set of categories of offers, which by far supersedes today's possibilities of branding and comfort class distinction.

### Time to destination

The required time for a travel from door to door is depending from several influences. The journey begins with the way to the airport, which may be accelerated by an enhanced **intermodality** of means of transport. In case of the incorporation of public forms of transport we could think of intermodal procedures of scheduling, baggage processing and check in and passenger identification, for instance during the bus ride or before entering the means of transport. This could at least for the passengers with a longer ride towards the airport result in a drastically shortened procedure for passenger and luggage processing at the airport, which would reduce the **time spent at the airport** (Goal 13.2), which is another important contributor to the overall travel time.

For those passengers coming to the airport by car or taxi, enhanced car storage systems could be helpful. Together with improved procedures for passenger processing inside the airport, this would on one hand reduce the time spent at the airport for the passenger and on the other hand would help to improve the airport's throughput (see Goal 14.1). The same technologies and procedures would improve the time spent at connecting and destination airports.

While the contributions to the travel time listed so far at first glance do not seem to be well suited for enhancement through the development of aircraft related technologies, there may arise opportunities by getting a better insight in the complete chain of time chunks spent between leaving the house and arriving at the journey's destination.

Between the airports the flight itself of course is the main contributor to the travel time (except for very short haul distances). The flight time is dependent of the chosen route (direct or connecting) which is one of the choices that have to be improved, again coming along with different fares for different choices. The offered **travel frequency** of the different kinds of connections (even from regional locations) has an important influence on the actual time spent during the journey. A considerably increased frequency of flights will have an impact on the needed size and economic flexibility of the aircraft to be used and in turn influence structural as well as ecological design parameters.

The other important contributor to the flight time of course is the **speed of the aircraft** used, and technological improvements of overall aircraft concepts, of high speed drag reduction as well as of speed flexibility (see Goal 13.1 "Punctuality") will be the key to reducing **travel duration**. As modern jet aircraft usually fly already in the vicinity of local shock patterns, the avoidance or decreasing of the sonic boom for higher speed aircraft is also a necessary area of research, even for very high subsonic flight regimes.

Despite positive market analysis the next generation supersonic aircraft are not likely to cover the sky before 2020. But the long lead time of related research and the tremendous amount of challenges to be tackled before environmentally acceptable and economically feasible designs will be possible, make it mandatory to put emphasis on related research in order to maintain competitiveness.

### Specific services

Specific desires of passengers concerning the ambience and the facilities available at the aircraft will be fulfilled in the aircraft cabins of the year 2020. For passengers desiring the convenience they enjoy at **home**, specific areas can be built, where, for instance, a calm atmosphere is maintained, reading or viewing television (the channels they prefer at home made available in real time) is the main activity.

Another area could be reserved for business. Meeting rooms on board, the complete set of communications passengers have in their offices will be made available there.

If families or other groups are travelling together, but not sharing the same activity pattern for the time of the travel and thus being placed in separated areas, a passenger intercom service could be arranged, allowing pax/pax communications, e.g. by using mobile phones in the cabin.

Areas of other ambience can also be provided, depending on the desires articulated by the passengers of the year 2020. In a leisure area, a set of gambling facilities could be available, if desired. Of course, advanced aircraft configurations (see Goal 13.3) would help arranging for this specific service approach.

Technology areas required are electronics, Electro-Magnetic shielding, communication devices, low weight-low cost – low energy design.

### Passenger needs

Like in other means of transport, the **health related aspects** of travel are of growing importance. Spending a long time (could be shortened, as explained above) in the same seating position is at least inconvenient. Larger and ergonomically enhanced seats which allow to change position or even provide massaging facilities will be of great value, especially in view of the growing average age of passengers in the developed countries.

Personalized **catering**, respecting dietary needs as well as personal preferences and being available at the time passengers wants to be catered, requires completely different catering procedures and facilities compared to what we have today, thus technological new approaches as well as enhancements are needed.

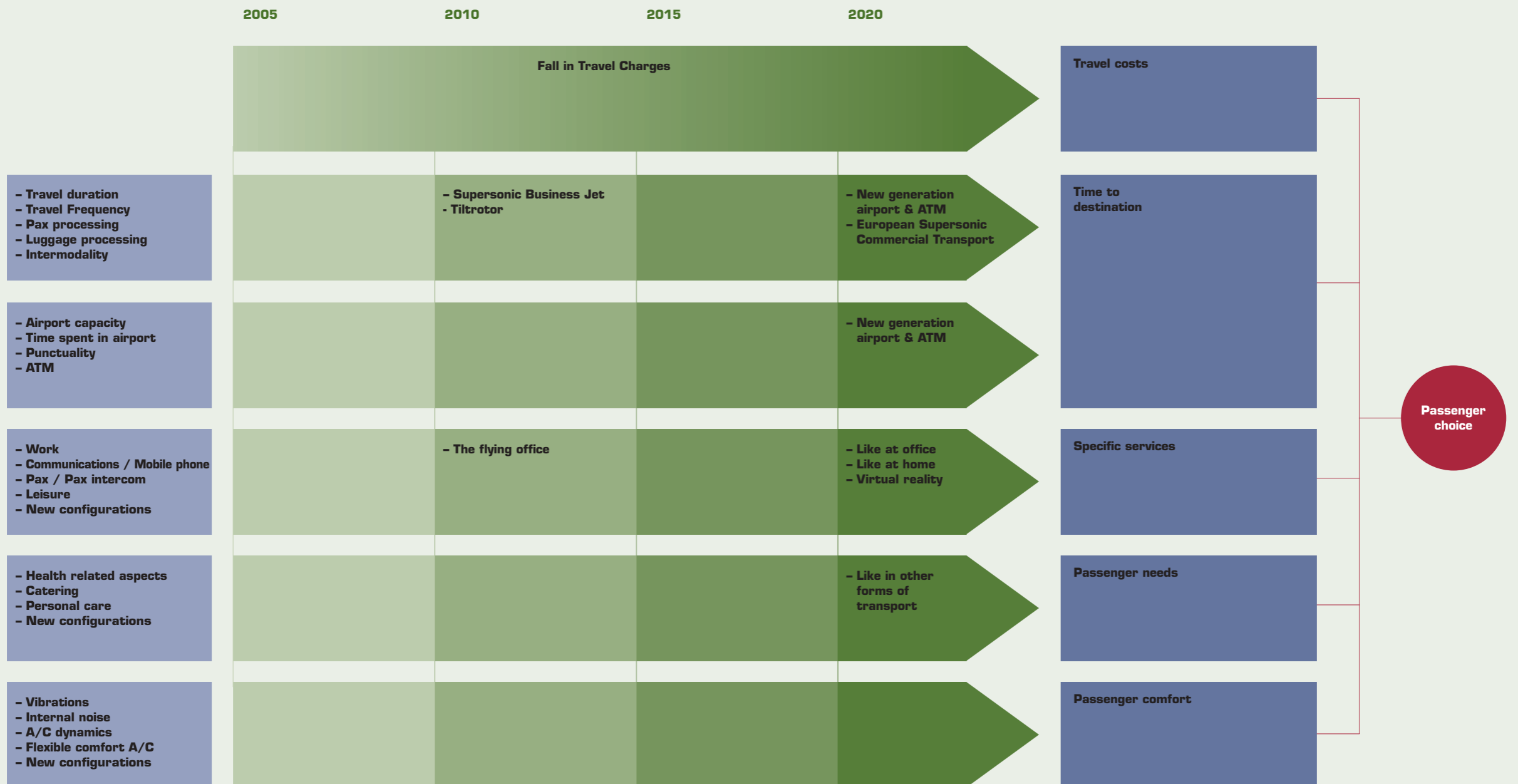
During long haul travel, **personal care** services (like coiffeurs, visagists, massage, showers etc.) or shopping areas could help making the travel an experience that is well remembered.

### Passenger comfort

Related to the human needs, but at a different priority level, the general aspects of comfort will have to be one of areas of choice a traveller will have in the year 2020. Comfort will no longer be handled only as a question of the seating width and catering quality. The passengers perception of **vibrations** and of the **dynamics of the aircraft** contribute to the general feeling of comfort as well. This is also true for the level of **internal noise**, both generated by the aircraft and by the surrounding passengers. Technologies for a customized sound system that actively suppresses unwanted noise for each passenger individually seems to be achievable in the future. Personalized **climate control** (including temperature, airflow and humidity) would help adapting the perceived level of comfort to the individual passenger's needs.

Because comfort is a subjective mix of many different contributions, the development of a common index of comfort is hopefully achieved within the near future. This index would help to define the most valuable fields of technological progress to achieve general comfort enhancements.

Figure 3  
Schematic overview of the Contributors and Solutions to meet the Goal of passenger choice



## Air-freight services

The air freight service Goal addresses the increase of air freight to be expected due to the increased competitiveness of air transport in comparison to land and sea transport (at least for goods of higher value) and the vision of a fully integrated air/land/sea transport system. Competitiveness can be directly related to the transport vehicle cost, speed and payload capacity and the cost of the crew required, the improvements expected from advanced vehicle configurations on one side and the transport system aspects on the other side as intermodal compatibility and operational constraints.

These building blocks of air freight service growth, as shown in Figure 4, define the avenues for technology development.

### Freighter aircraft cost

Freighter aircraft cost are composed by the same elements as already addressed in the fall in travel charges / cost reduction technology avenues of Goal 13.3. With respect to passenger aircraft modified into freighter aircraft the achievements of Goal 13.3 in the area of design to life cycle value, maintenance and sustainable architectures will play an important role in achieving competitive freighter aircraft cost.

### Freighter aircraft crew requirements

Crew cost for freighter aircraft operation are of the same importance as for passenger aircraft but with the advantage of being in a position to exploit the technological achievements much earlier, on a rational basis without being dependent on more emotional factors like those governing passenger acceptance.

This does not mean that the level of safety will be lower, targets for the probability of hazardous situations will be identical due to the danger a freighter aircraft accident can impose on any populated area, but it eases the demonstration of safe and reliable aircraft operation and will support the application of automation technologies onboard of passenger aircraft.

Therefore freighter aircraft are expected to be the pilot application for fully automated aircraft. The interface to the ATM system with respect to flight path negotiations will be less complex due to less stringent flight path level and manoeuvre loads requirements (no passenger ride comfort) and time of arrival requirements (no transfer passenger driven time slots, turn around time requirements in general). The interface requirements of an automated vehicle with respect to airport infrastructures (e.g. ground / taxi guidance systems, auto-start) might become a blocker for mixed passenger / freight airport operation and will be satisfied best by special freighter ports (like unused military airports) which could result from intermodal compatibility requirements of the overall transport system anyhow.

Based on the technological achievements of the crew cost avenue of Goal 13.3 freighter operation with a supervisory type of cockpit crew will start well in advance of passenger aircraft. Even a fully automated flight of a freighter without a crew present in the cockpit could be achieved at the end of the next two decades. Security measures need to be explored.

### Airborne freighter configuration

Freighter aircraft configuration will develop along two different lines.

- The first line will have its roots in fixed wing aircraft configuration and will lead to specific configurations without the restriction of passenger driven design requirements, i.e. roll rate constraints for passenger compartments in blended wing/body configurations, cabin pressurisation, passenger boarding flow, emergency evacuation etc. Advanced aircraft configurations developed along the technology avenues of Goal 13.3 will feed into this development at all gates of the freighter configuration avenue.
- The second line will develop along door to door operation scenarios which for the time being are only feasible by rotorcraft freighters but which might include in the future "lighter than air" configuration as well. Those configurations will include also hybrid type of aircraft using "lighter than air" technology for additional lift generation, combined with fixed wing or tilt rotor designs.

Road traffic congestion causing restrictive road regulation (constraints) could act as "enabler" for new freighter configurations. Very large payload capacity aircraft (300 t) might be taken into consideration.

### Intermodal compatibility

Up to now land and air freight traffic systems are not integrated into one “seamless” system, neither road based nor rail based land transport. Cargo ground handling is mainly designed around the constraints of each individual transport system and not by efficient turn around concepts (except the case ship-train intermodality which is well developed).

In short term improvements can be envisaged in cargo ground handling mainly based on cargo packaging concepts, but also on advanced technology for cargo tracing and ground handling systems / tools. Infrastructure design also plays an important role, inputs from Goal 14.11 / airport capacity will influence the intermodal aspects of the infrastructure layout.

Intermodal compatibility will become easier to implement with the development of pure freighter aircraft configuration where the aircraft design can take into account transport system interface aspects without the constraints superimposed by passenger transport needs.

### Operational constraints

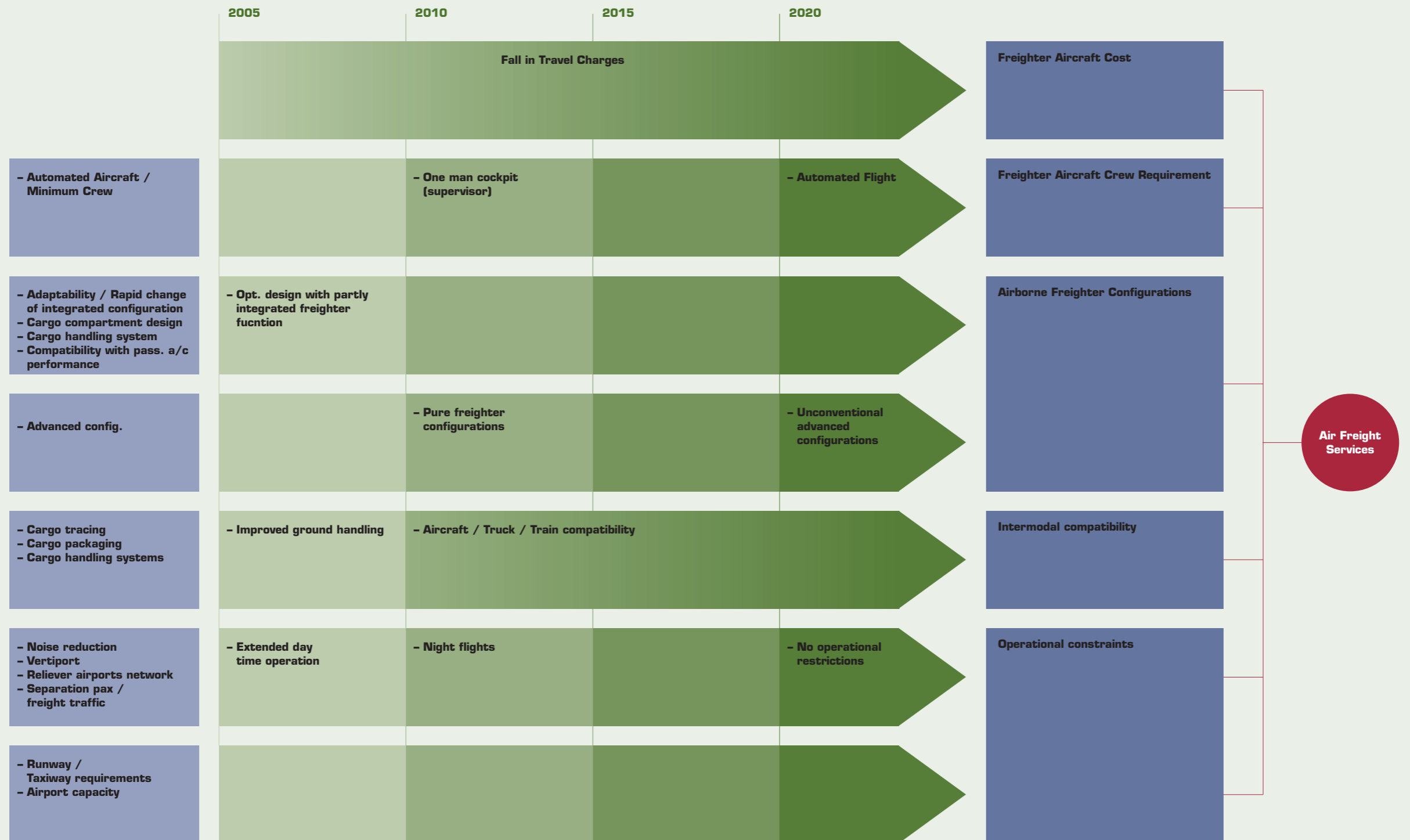
Today's operational constraints are mainly airport capacity driven or caused by the different noise level of aging freighter aircraft. To overcome the constraints it is essential that aircraft performance characteristics, especially with respect to environmental issues, will not be different between freighter and passenger aircraft.

The result from the technology development over time to meet the Goals 14.5/6 (noise reduction) will have to be applied to freighter aircraft designs accordingly. The same applies to the results of Goal 14.11 (airport capacity) so that the operational constraints can be reduced in a first step, leading to extended and even night time operation, minimising the interference of passenger and freighter aircraft slots.

The separation of freight and passenger flow which might lead to specially designed freighter ports equipped with optimised runways, aprons and interfaces to the land/rail freight transport system has to be analysed as well with the objective of unrestricted freighter operation in support of the competitiveness Goal. The “Vertiport” concept might also bring an important contribution in that specific area.

Nevertheless once the freighter aircraft is airborne its performance with respect to feasible trajectories and the compatibility with the next generation ATC requirements should not differ from the advanced passenger aircraft characteristics.

Figure 4  
Schematic overview of the Contributors and Solutions to meet the Goal of increased air freight services



## Competitive supply chains and halve time to market

The predicted increase in air traffic drives the development of the air traffic system such that the functionality of the overall system is becoming more integrated, e.g. with extended integration between ATM and the Flight Management System (FMS). Further, competition from other means of transport as well as between airlines is driving a continuous evolution of services provided on-board, e.g. business environment integrated to internet, as well as smoother integration with ground handling. Recent events have shown the need to be able to quickly respond to new security threats and maintain the ability to stay ahead with security measures. This may be further accentuated as systems are becoming more integrated.

From the above it is evident that the air transport system develops in a direction where the total interaction in the system is growing and a system-of-systems approach with adaptability and scalability is needed. The systems become increasingly complex and drive the need for new technologies and innovations. New technologies and innovations present potential for new capabilities that, if implemented, gives more competitiveness for Europe.

The European supply chain is unique in its complexity and its ability to achieve world-class systems. The European aerospace supply chain has repeatedly demonstrated an ability to develop competitive and world-class technical solutions. However, this process of actively shaping the supply chain as an integrated part of the early stages of the product development suffers today from having longer lead time than comparable US processes. This lead time disadvantage is at risk to accentuate as change rate and complexity is growing.

The challenge, reflected in the Vision 2020 goals to have a competitive supply chain and a lead time reduction of 50%, is to develop a European value chain system which maintains and increases the innovation advantage and gains in terms of lead time competitiveness. Two lead times are considered important, first TTM (Time To Market), which is the lead time for bringing a new solution to the market, second TTD (Time To Delivery), which is the lead time from order of an existing product until it is delivered. Short TTM is providing functional flexibility if it can be achieved both for new products and as retrofit into existing products. Short TTD is providing volume flexibility as it increases the airlines possibility to respond to increases in demand quickly.

In the development of aircraft, and other complex highly coupled systems, there is a strong linkage between the product developed, its supply chain and the process applied. Each program applies a combination of product technologies, supply chain possibilities and supporting processes in order to achieve an optimal system both in terms of cost, performance and degree of innovation throughout the products expected life. As the requirement on the product is to be flexible, adaptable and sustainable in an environment with limited predictability, the process and supply chain need to support this throughout its life. Potential to improve exist throughout all stages of the product life cycle and the ability to respond to requirements as early as possible in the life cycle is key to achieve affordability. As Figure 5 shows, three research avenues are identified as key to achieve the Goals and respond to the new requirements.

### Integrated supply chain (resources aspects)

The current supply chain is well integrated for the later design and manufacturing stages of the life cycle as long as the conditions are relatively static. However, at early stages of the product life cycle there exist a huge potential to integrate the supply chain such that more dynamics and intense innovation fields could be achieved. The long life cycle of aerospace products and the wide range of life cycle time for subsystems, ranging over an order of magnitude, make it a challenge to maintain product integrity and integration of new capabilities. R&T foreseen along this avenue focuses on the possibility to provide a dynamic value chain at early product stages, the ability to rapidly implement new functionality and to cut TTD. Research should:

- Develop management systems to increase the dynamics in the supply chain and being able to better optimise the innovation and value flow through-out the supply chain.
- Achieve integrated product definitions in order to improve communication possibilities.
- Enable modelling and simulation use such that the integrated product definition will further increase knowledge propagation speeds.
- Develop manufacturing systems and logistics such that responsiveness is improving throughout the supply chain and risks for cost and lead time penalties are reduced or eliminated.
- Achieve manufacturing methods reducing significantly both recurring and non-recurring costs while supporting volume flexibility.
- Develop necessary demonstrators for new aircraft architecture in short timeframes.

Having achieved these objectives in 2020, the virtual enterprise is fully realized. The value chain of 2020 will be responsive and cost effective having very competitive TTM, TTD and rates of innovation as well as robust mechanisms to maintain product integrity in a world of continuous change.

### Systems Engineering (process aspects)

Systems Engineering is the holistic approach to competitive product realization including methods, tools, processes and working procedures. As the air traffic system becomes more integrated, and the demand for flexibility and responsiveness is growing, the conditions for systems engineering are changing. New Systems engineering concepts have to be developed. Research should:

- Provide development support for new architectures, e.g. open architecture, supporting flexibility and adaptability, interoperability on systems of systems level and to maintain the integrity of the system
- Expand possibilities with modelling and simulation for early knowledge generation and communication (eg. the use of digital mockups changed the situation in the 90's)
- Provide Integrated Product Definition as the basis for a simplified mastering of the product throughout its life
- Provide Verification, Validation and Certification methodologies such that they in a cost effective manner contributes to the flexibility of the systems.
- Develop interoperability principles that allows flexibility and integrity on system of systems level (e.g. ATM integration).
- Provide Management Systems supporting efficient systems engineering throughout the supply chain.

Systems Engineering in 2020 will support the development of products in the virtual enterprise that are open to cost effective implementation of new functionalities not known when the initial design is done. Systems engineering is supporting the re-use of legacy solutions and established knowledge with openness to innovation and change that brings new value to the aircraft and supports the long term product integrity.

### Design for life cycle value (product aspects)

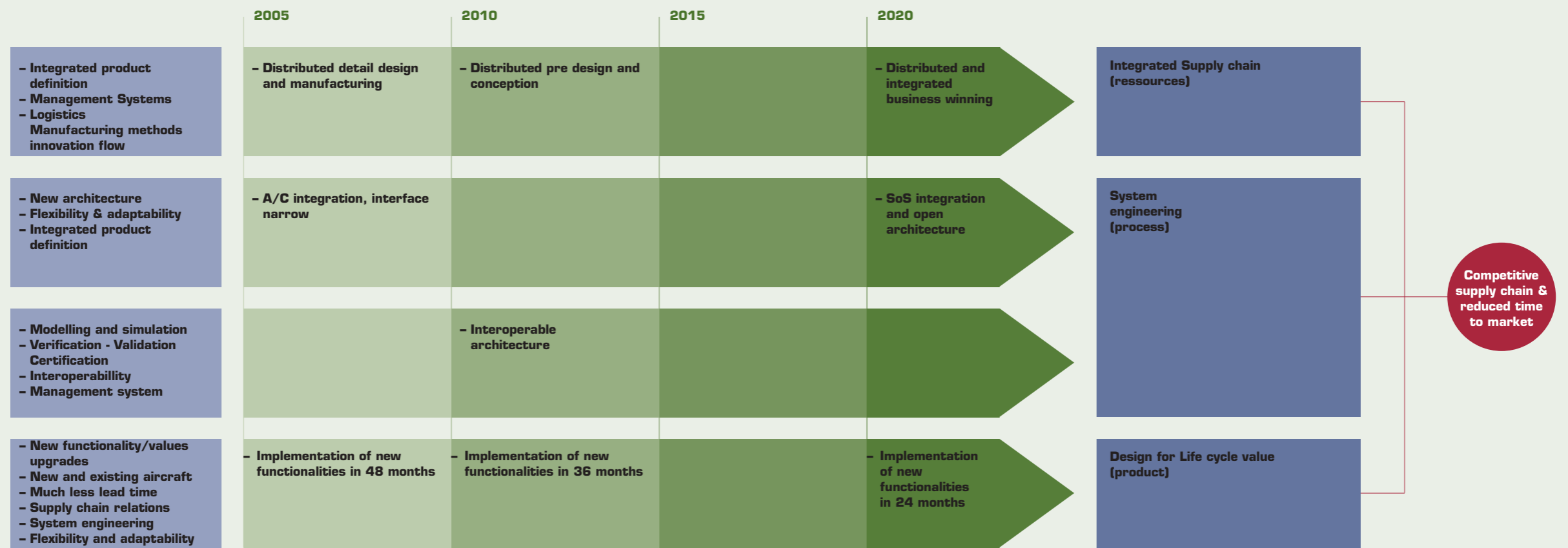
The way aircraft are developed today creates products where the threshold for change is high and new functionality is normally introduced in new aircraft with long lead times, while the trend should be to be able to integrate new functionality in new and existing aircraft with much less lead time.

In a situation where change is continuous and inevitable, changes will be introduced in both new and existing aircraft. As the architecture for a new aircraft is based on existing and new solutions, introducing a solution to a new aircraft will be similar to bring a new solution to an existing architecture. Research should:

- Develop applications for rapid implementation based on systems engineering and dynamic supply chains
- Enable flexibility and adaptability including possibilities for easier customization
- Provide methodology to manage value over time for the aircraft system including identification, prediction, trade-off, implementation, maintenance
- Develop abilities to predict the importance of new functionalities / values and allow cost effective upgrades throughout the life cycle.

Design for life cycle value in 2020 benefit from the improved supply chain, systems engineering and the above enablers such that new values can be implemented throughout the life cycle with drastically reduced lead times. Implementation of substantially new functionalities will be expected to take 24-30 month in the year 2020. Current lead times for a new commercial aircraft model ranges from 48-60 month.

Figure 5  
Schematic overview of the Contributors and Solutions to meet the Goal of a competitive supply chain and reducing the time to market



## Contribution to other Goals and various other considerations

The Goals set out in Vision 2020 and in particular those considered in previous sections, will only be achieved by considering the interaction and cross-dependency of all aspects of the air travel system, along with its multitude of factors. This can best be achieved by generating a Synthetic Environment<sup>(3)</sup> representing the complete Air Transport System.

This will in turn, lead to interaction between design optimisation for different aspects of operation and may result in compromises between differing requirements or imperatives. The overall vision will only be achieved if we adopt and drive through a holistic approach to designing an optimised air transport system.

For example, most of the considerations on "Emission" or "Noise" will have two groups of factors; primary and secondary. All these factors must be considered in order to achieve an optimised result.

As just one aspect of this, atmospheric pollution from civil airliners will obviously be affected by primary design factors regarding the engine and airframe. However, the overall pollution from the air transport system will also be strongly affected by secondary factors such as minimisation of time spent circling airports to await landing slots, engine run time due to self-powered taxiing around airports and, to a lesser extent, by engine running to warm the engine structure prior to flight.

The purpose of this section is to identify this secondary, sometimes less obvious, factors, which must be considered as part of the total picture if we are to achieve the Vision 2020 Goals.

### The aircraft in the airport environment

It is in the airport environment, going from passenger arrival at the airport through to take-off that many of the critical social parameters are encountered. From the passenger viewpoint, aspects such as punctuality, minimal delays, convenience and comfort obviously figure largely. From the general population standpoint, take-off noise, atmospheric pollution, landing noise, etc will be paramount.

One of the first considerations in achieving our targets is the siting of airports. There is little point in having an extremely efficient airport

with minimal pollution within its perimeters if the only way for the travelling public to reach the airport is to use road vehicles, private cars, etc, along with their high pollution levels per individual traveller.

Thus the first lesson of location is that there should be good public transport links using modern high-efficiency, low-pollution systems.

These, in turn, should interface smoothly and easily with the systems of the airport, leading to greater use of baggage check-in at railway station of origin, perhaps.

This is as a matter of fact more a question of security and facilitation than of operational nature. The main constraint here are the legal requirements and the actual feasibility of early off-site check-in, including baggage processing from the first point of interaction between the passenger and any mode of transport (the journey ultimately, of course, having an airline leg).

In considering the route of a passenger through the airport, speed of check-in, baggage check-in etc, and security checks, obviously our primary factors in reaching the punctuality and low delay levels envisaged. However there are activities that could also be considered as having a strong impact on overall efficiency, such as the unnecessary transport of duty free alcoholic drinks and tobacco products around the world. Neither of these is desirable in any volume on an airliner, if only due to the fire hazards involved in a crash, but the weight of such products carried around the world unnecessarily must add significantly to the overall fuel burden and hence pollution.

Once we have the passengers on-board the aircraft, luggage loaded and doors closed, the real opportunities for pollution reduction manifest themselves. All passengers have been frustrated by the time often spent between backing off from the gate and actually reaching the take-off runway. During this period, all aircraft engines are running, at least in idle, and are the sole means of propulsion across the ground. This operation generates pollution at ground level, where it has most direct effect on the surrounding population and consideration must be given to methods of minimising this delay.

(3) Synthetic Environments : An amalgamation of modelling and analysis software tools operating within a managed, consistent and coherent data framework. A synthetic environment might at the one extreme encompass the complete problem domain, but will more likely address one or more specified elements of that domain.

A complete synthetic environment might be fully contained at one site or might operate across a number of locations through some connectivity arrangements. Within a single synthetic environment, any function might typically have a number of models operating at different degrees of fidelity, each suited to a particular purpose, but all operating using consistent data (assumptions).

In the aerospace acquisition domain, the components of a synthetic environment might include operational analysis models, scenario models, costs models, reliability models, performance models and simulations (including man-in-the-loop simulators) and perhaps actual interactions with real test hardware.

Equally, a holistic approach to an air travel system would not place airports in heavily populated areas, such that all take-offs involve a “scramble for altitude” in order to minimise noise pollution, but would rather site them in more remote areas, perhaps on the coastline, with the high speed rail transport links mentioned earlier.

### **The aircraft In-Flight**

Once airborne, the aircraft then has to travel safely, quietly and economically to its destination. The ability to choose, or be assigned, optimal operating levels for efficiency standpoint and optimal routings is a primary factor in this, and has led to different approaches to advanced air traffic management systems. The European one is projected to be a “free flight” system whereby the pilot has ability to choose routing and altitude, within constraints, once clear of airport airspace.

Over the last six months, though, an important new factor has entered the equation. The terrorist attacks on New York and Washington using hijacked aircraft has led to a significant degree of re-thinking of the best way of controlling aircraft in flight, and ways in which major deviation could be controlled or prevented. This, in turn, may lead to a more rigid assignment of routes and altitudes, along with monitoring and early alerting or automatic control of any unjustified deviation from routing.

At this stage, it must be also stated that assigned routes are only important insofar that they add an element of predictability. ATC radars are usually secondary radars, that do not track the actual aircraft, but a signal transmitted by its navigational aids avionics. To put ATC in a position to effectively control aircraft, ATC should be performed with primary radars, which is usually the case for the military, but then in turn, you would not have an aircraft identification, only a spot on a screen – a series of spots, rather.

Equally the events of the 11<sup>th</sup> September will introduce long-term constraints on the routings available to civil airliners when leaving or approaching airports near major population areas or major terrorist targets.

The well-known problem of “queuing in the air” for landing slots must be addressed if pollution and delays are to be minimised. Again, this is an operational and ATM factor much obviously including the airport component, that must involve the aircraft operation as a significant part of the solution. A system must be developed to provide for “just in time” arrival for the landing slots available. This could involve aircraft diverting slightly in-route or flying a little more slowly or at a different altitude such that the effect on pollution is minimised.

### **The aircraft at destination airport**

Once on the runway, the aircraft then has to taxi to its appropriate unloading terminal. In all too many airports this results in several tens of minutes of further delay, characterised by a series of stop-start manoeuvres under engine power. Again, planning has a lot to offer but the major gain could perhaps be in towed manoeuvring (despite the fact that some past experiences demonstrated limitations) with engine shutdown after exiting runway. This is already adopted in some airports for noise reasons to docking bays close to perimeter fences but could be considered as an overall pollution wear and tear, etc, reduction process. More systematic towing procedures from parking positions, maintenance areas, engine test facilities will have also to be envisaged.

Once docked at an unloading station, efficiency in reuniting passengers with luggage and duty free goods and getting them onto rapid transport systems to their final destination is obviously just as important as in the departure airport.

# Conclusions and recommendations

A time bounded study has been conducted aimed at identifying the most appropriate items (in term of Solutions, Contributors, major steps, technology targets and associated technology requirements) to reach the Vision 2020 Goals in relation with the "Quality and Affordability" and the "European industry competitiveness" challenges.

With broad stakeholder participation it was concluded that aircraft products in the 2020 time frame will benefit from a new generation of architectures that allows the implementation of new innovative functionality within a sharply reduced timeframe utilizing systems engineering that opens up the full potential of the virtual enterprise.

With respect to the products and technologies required to meet the Vision 2020 objectives it was recommended that **a set of major steps** could serve as intermediate targets (in terms of technology readiness) to be achieved by 2010. These were identified as, for example,

- One man cockpit aircraft
- The quiet aircraft allowing night flights
- Flying office
- The pure freighter aircraft
- The tilt-rotor
- Etc.

While at the 2020 horizon, some global concepts have been put forward, eg.:

- Supersonic business jets
- Pure freight, fully automated aircraft than can be operated 24 hours a day
- Hybrid type freighters

At the same time, it was recognised concepts that would that would affect the European Aeronautical Community post 2020 would need to be started during this period, therefore it was recommended that there should be a focus on research technologies which would stimulate an allow novel concepts to be introduced eg.:

- Plasma research
- High performance propulsion research

It must be pointed out that the question of decision making process (which would lead to prioritisation) shall only be addressed in a later release. However such a decision making process should take into account the following elements (or criteria):

- Technological relevance
- Costs / funding
- Consequences for the different stakeholders
- Enablers / blockers
- Technology trends

It is recommended that this topic should **build upon a of a well defined and agreed aeronautical R&T taxonomy** as well as the consideration **of a set of consistent relative weighting factors**.

During the course of the discussions, several considerations have also been brought in terms of facilitating aspects (enablers). In this respect it is clear that the European research infrastructures, capabilities and processes are of a particular importance for the setting up of the Strategic Research Agenda. In this context, **it was felt the following points should be made** :

- Europe has world class universities / schools but fragmentation due to regional / national variations is encountered
- Europe has world class Research Establishments, but more harmonisation / integration would be desirable
- Europe experiences some obvious weakness in transferring basic research into applied research (due to funding, motivation?)
- The European way of doing more often favours evolutionary (not revolutionary) approaches.
- The European aeronautical stakeholders suffers from a lack of visibility with respect to breakthrough technologies and identified a striking need for high risk research
- There is disparity in terms of financial support from defense sector (dual use applications) in Europe compared to the US

Powerful computer capabilities (through supercomputers or distributed facilities), powerful and secured networking as well as a policy for technology demonstrators with objectives ranging from the simple feasibility of a new principle or concept to actual full prototypes which integrate a set of new developments to be implemented in competitive products have been identified as key success factors.

An example is the unmanned freighter, showing the potential of simplification due to elimination of the need for an on-board pilot working environment.

The capacity of the air traffic system is heavily dependent on a holistic approach to the integration of system-of-systems, e.g. the aircraft integration to ATM and ground handling.

# Glossary

A/C	Aircraft
ACARE	Advisory Council for Aeronautic Research in Europe
ARTE 21	Aeronautic Research and Technology in Europe for the 21st Century
ATC	Air Traffic Control
ATM	Air Traffic Management
BIT	Built In Test
ESCT	European Super-sonic Commercial Transport
FMS	Flight Management System
IPCC	Inter-governmental Panel on Climate Changes
NASA	National Aeronautics and Space Administration
Pax	Passenger
R&T	Research and Technology refers to developing new technologies – more specifically it covers basic research, concepts, technology development and technology integration & validation
SRA	Strategic Research Agenda
SSBJ	Super Sonic Business Jet
TTM	Time To Market
TTD	Time To Delivery
UAV	Unmanned Airborne Vehicle