The Challenge of Air Transport System Efficiency

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Executive Summary

The objectives laid down in the Vision 2020 report are extremely ambitious for European Air Transport. They, and other figures, forsee a tripling of traffic in Europe, both in terms of passengers and flights, with a punctuality target of 99% of flights departing and arriving within 15 minutes of their timetable in all weather conditions. Passengers should not have to spend more than 15 minutes in the airport before departure and after arrival for short haul flights, and 30 minutes for long haul flights.

The challenge set was how to achieve these objectives through investigations into the Future Air Transportation Environment, the aircraft as part of the Air Traffic Management (ATM) infrastructure, Airports and security issues.

The main conclusion of the work undertaken in the different fields was that the Vision 2020 objectives would not be reached unless there was a **paradigm shift** in the way the Air Transport System is conceived and operated. The Research and Development (R&T) paths which pave the way towards these changes are the following:

Optimising the use of existing ATM-Airspace capacity

There is a need to optimise the usage of existing ATM and airspace capacity while new sources of capacity are developed. Measures for doing this include implementation of techniques which balance and organise traffic according to the capacity constraints and possibilities. Dynamic Flow Management techniques would need to be integrated into possibly new ATC operational concepts through a consistent, end-to-end trajectory-based information management system.

Removing the ATM-Airspace Capacity Barrier

New Capacity needs to be created, and this is likely to need a shift in the Air Traffic Control (ATC) paradigm, by which the ground Air Traffic controllers would redistribute their tasks, including delegating some tasks to the aircraft. This is likely to be the most significant R&T topic in the coming years. The extent and scope of tasks to be distributed or delegated, the new operational concept which would sustain such changes will depend upon the maturity and desirability of new automated systems, including more autonomous aircraft-based capabilities and/or more advanced, dependable ground-based systems in support to human operators. It will also rely on the availability of a robust, broad-band telecommunications infrastructure supporting System Wide Information Management.

Maximising current airport performance

The airports are likely become an increasing constraint upon the development of the air transport industry in Europe. There is scope to further improve efficiency and capacity with the existing airport infrastructure, by exploiting measures such as: enhanced operational concepts, supported by new decision-making or decision-support tools should ensure more efficient use of the airport infrastructure, even in adverse weather conditions. Among other things, reduced separation minima, multiple runway optimisation, new landing aids and A-SMGCS[1] are seen as key R&T topics.

Nonetheless, extensions to the existing airport infrastructure are seen as an inevitable requirement if three times the traffic is to be handled. However, the ability to construct new airports or new runways is expected to become increasingly difficult because of environmental constraints, especially in the high population density areas where most of the demand for air transport originates,

For this reason, there is an urgent need for societal and economic studies investigating the evolution perceptions of aviation in general, and airport safety, economy and noise issues in particular, with the goal of identifying ways of ameliorating unduly negative perceptions that hinder the development of aviation.

It is also recognised that there is scope for new operational and business concepts, by which, for instance, traffic could be redistributed among cluster-organised airports, interconnected through ground (high speed trains) or rapid air connections (via new generation rotorcraft, for instance).

The Airport of the Future

Airport processes, for passengers and goods, luggage and aircraft have been identified as one of the key areas to be addressed in R&T. The current processes for passenger check-in, and security screening show little room for the level of improvement which is required to meet the Vision 2020 objectives. Indeed, if the required level of security for air transport stays high, there is a definite need to develop new concepts for the security checks in order for them to be more efficient. Similarly, tripling the number of passengers is likely to imply larger passenger terminals, in which passenger movements would need to take place in an extremely rapid manner. New passenger movements concepts therefore need to be developed.

1. Advanced Surface Movement Guidance and Control System

Introduction

The overall optimisation of the airport processes, involving a wide range of actors, including non professionals (the users) is the key outcome of this path. In order to achieve this optimisation, transparent and end-to-end information exchanges, (including those with passengers and using new portable technology), are seen as being of particular importance, together with Airport Collaborative Decision Making, and these are regarded as key enablers for this path.

Seamless European Global System

For the European Air Transport System to operate seamlessly, there must be interoperability between all its components. Interoperability applies to both human and machine. Hence, systems interoperability, global world-wide standardisation as well as labour mobility in Europe were seen not only as necessary for a seamless European system, but also as a sine qua non condition for the competitiveness of the European Industry.

Seamlessness also means having an integrated airport-airspace approach which would find the optimal organisation of the European air transport infrastructure, for instance in the configuration of the network of trans-national en route or terminal control centres.

Robust, highly resilient and secure communications, together with an advanced navigation and surveillance infrastructure would be needed for this seamless system to function effectively and efficiently.

The situation for the air transport in 2001 is used as a baseline for the work to be carried out in ACARE. Key statistics for 2001 are the following :

– A Passenger traffic of about **500 Million** passengers per year
– An aircraft traffic of about **7.5 million** flights per year
– An average delay per flight of **3.5 minutes** attributable to ATC, which represented about 30% of all delay causes.

The general assumptions used for the ACARE work programme were that there will be overall growth in air traffic during the next 20 years. Even though it was recognised that there could be some temporary decreases in the European air traffic, there was a general consensus that the overall tendency would be sustained growth, driven, for example, by economic effects due to the extension of the European Union.

There was also wide acknowledgement that there was a need for a quantum leap in some aspects of the way air transport is operated, in order for this growth to be sustained. Indeed, the Air Navigation Services infrastructure will probably reach its saturation limits well before 2020, if there is no paradigm shift in the way the traffic is controlled and managed. Similarly, airports are likely to become increasingly saturated, both on the landside and airside: environmental constraints are expected to become more and more stringent; and the passenger and luggage handling processes need to be optimised (particularly in an increased security environment).

Here again, it was recognised that there would need to be a real innovative approach to airport saturation issues, if one wanted to achieve the GoP objectives. Another issue, specific to airports, which is seen as a challenge needing to be addressed, lies in the fact that they are operated in a rather isolated manner, both regarding day to day operations and the longer term perspective, with the consequent lack of process and systems standardisation leading to duplication of effort and expenditure.

External factors, such as economics or political issues, were deemed to have a long term impact, more on the behaviour of the air transport users than on the general trend towards growth of the sector.

The emergence of new technologies, especially in the field of communications, is seen to offer opportunities for new operational concepts. Developments in other fields of the aeronautical industry, which would lead to high performance, safe and affordable air vehicles that could become complementary to “conventional” aircraft, were also seen as offering the opportunity for new operational concepts.

Background

This document is an input to the Strategic Research Agenda (SRA) and considers what must be done to achieve a Vision that is nominally set around the year 2020. In practice, aspects of it consider some even longer term issues concerned with Efficient Air Transport, since the development of the industry will continue beyond that date. For clarity Efficient Air Transport is defined as

"the movement of aircraft, of all types, and their passengers, through European airports and sky, in a timely and economic manner, without undue constraints on their preferred flight trajectories (aircraft), journeys (passengers) or departure and arrival times.".

The Current R&T Situation in Europe

An ARDEP[2] analysis is performed on a yearly basis together with the major Stakeholders in ATM R&T (including one or more organisations from each of France, Germany, Italy, Netherlands, Spain, Sweden and the United Kingdom) as well as the EUROCONTROL Agency, European Commission (EC) and the European Space Agency (ESA).

ATM R&T Projects

The analysis reports that, each year in Europe, about 300 projects are carried out in ATM R&T, excluding the Global Navigation Satellite System (GNSS) infrastructure projects. This includes the visible (publicly funded) part of industrial projects while the fully privately funded industrial projects are not covered.

Overall, about 200 Million euros of expenditure is visible each year on ATM R&T activities. Reality might be well above this figure.

Each sponsor defines his priorities in view of his governing body's requirements. Even if some co-ordination via different international mechanisms is taking place, the different sponsors' ATM R&T programmes are defined separately.

Considering the twelve independent organisations influencing the ATM R&T programmes and resources, the relatively smooth evolution of the resources allocated to the ATM domains is striking. The individual strategies seem to smooth out when considering all of them together. Also, the relative importance or priority given to individual research domains does not appear to be affected by specific calls for emergency actions, for instance action to reduce delays. It can, of course, be argued that ATM R&T is by definition not supposed to react with short-term actions. It might also mean that the way of managing ATM R&T is following tradition and the programmes have considerable inertia. Thus it is expected that the SRA will contribute to focusing and co-ordinating them.

Comparison with the USA Airports And Aircraft Operators R&T

The ARDA analysis shows that the FAA and NASA together sponsor ATM R&T activities for about 300 M euros per year covering the same types of activities as in ARDEP. NASA is very much oriented towards Decision Support tools and Airport simulations. The FAA develops a National Research Plan every year. NASA developed two main programmes the AATT (finishing) and the new VAMS simulator project (starting in 2002 and finishing in 2006 close to 80 M euro per year). We should however note that the global figure (300 M euro) is an under-estimation of the actual money spent on R&T in the United States, given the fact that it takes into account only Federal Aviation Administration (FAA) and NASA sponsors, and that there is no structured way (as in ARDEP) to capture all ATM-related research (notably in Universities, not-for-profit organisations such as MITRE, and others.)

Airports' and Aircraft Operators' R&T

The highly competitive environment that the Airport Operators and Aircraft Operators have been facing in the past few years has forced them to focus on their own competitive advantages, giving priority to short term, productivity-focused activities rather than long term R&T. There is consequently little evidence of European scale R&T programmes, even though some recent initiatives like the EC Passengers Rights Initiatives, would encourage European co-ordination.

The consolidation of the market and the emergence of "collaborative" measures should give rise to an increased participation of aircraft and airport operators in European R&T. The consolidated market will expect economies of scale to take place, the scope of its operations being by nature wider than a single country. Aircraft operators will thus expect standardised procedures to take place, not only at the ATC level, but also in the airport processes, so as to minimise their need to adapt to specific airports' requirements. Further, AOC operations will need to be based on system-wide information, which influences all aspects of telecommunications infrastructure requirements (Airlines Operation Communication (AOC), Airlines Passenger Communications (APC), ATC...)

2. Analysis of R&D in Eurocontrol (Organisation) Programmes

Challenges and Goals

Main Actors

In Europe the ATM R&T mechanism can be classified around R&T sponsors and providers. The main sponsors are the European Commission, the EUROCONTROL Agency, the major Air Traffic Service Providers (ATSPs) and Industry. The main R&T providers are the ATM R&T Centres of Expertise (usually belonging to,- or strongly connected with, the ATSPs), Universities and Industry. The European Space Agency is conducting enabling work that is relevant but not included as ATM R&T.

Airports also sponsor R&T, but in a local, fragmented way that is difficult to track at a European level.

Required Funding for R&T into a more efficient Air Transport

The Vision 2020 objectives provide extremely challenging targets for R&T in Air Transport. In particular, tripling the amount of traffic and passengers that the system can handle will require major changes in the way the system is conceived and operated.

Today's level of R&T spending represents only a proportion of what would be needed to implement the Vision 2020. The emphasis of the current R&T spend is more on the technology side, rather than on operational aspects, such as integrated, kerb-to-kerb concepts. Moreover, as mentioned above, very little Europe-wide and co-ordinated R&T currently takes place in the field of airports and airlines operations.

The best estimate coming from the work on Efficient Air Transport for the SRA indicates that at least a tripling of the current figures, which would represent a sum of 600 Million Euro per year, will need to be spent on Air Transport R&T.

The Goals for European Air Transport

Starting from the Vision 2020, the investigation into the challenge for Efficient Air Transport has focused, in its first pass, on a subset of Vision 2020 goals and has elaborated them to identify the challenges and enhanced capabilities that will be required.

In the main, the goals presented in existing material are not quantified and remain at a fairly high level. More specific, quantified objectives for each goal remain to be developed in order to be able to derive required performance.

Enhanced Capabilities

Enhanced Capabilities provide the top-level response to the strategic need for change in response to the 'changing circumstances' that would be described in the Environment and Context Scenario. They drive the need for operational and technical change, in particular.

Linking Goals to Enhanced Capabilities

The following table demonstrates how the goals are linked, via challenges, to enhanced capabilities.

It should be noted that a number of enhanced capabilities contribute to more than one goal or challenge and this is noted in the table, without repeating the sets of enhanced capabilities for each goal.

Later in this document, there is discussion of the activities and developments that would lead to each enhanced capability and the main R&T issues.

It should be noted that there are a number of potential, alternate, pathways from today's situation going into the future and some key decision points can already be identified as discussed in the section "Contributors".

Vision 2020 Goals	Challenge Goals	Contributor	Enhanced Capabilities Required
An air traffic management system that can handle 16 million flights a year with 24-hour operation (a seamless air traffic system that copes with up to three times more aircraft movements than today).	An air traffic management system that can handle 3 times the number of a/c movements overall and at least 3 times growth in the busiest airspace volumes, compared to today Increase ATM Capacity to handle 3 x growth in air movements	- Airport security	- Airport security
	Increase Airport Capacity to handle 3x growth in air movements	Create new ATM/Airspace capacity	Paradigm shift/ alternate solutions
			Co-operative ATC
			Move the whole ATM system to a 4D trajectory basis
		Optimise use of existing ATM/Airspace Capacity	Flexible and dynamic use of airspace ATFM-ATC Integration/Dynamic ATFM CDM Move the whole ATM system to a 4D trajectory basis
		Get the best available information to each process	System-Wide Information Management (a key enabler)
	Increase Airport Capacity to handle 3x growth in air movements	Define the airport of the Future	[see below under Vision 2020 Goal Time spent in airports]
			Overall Integration of airport Processes
			Futuristic airports
			Innovative Passenger and Luggage Processes
			CDM
		Maximising airport performance	Improve runway performance

(1/2)

Vision 2020 Goals	Challenge Goals	Contributor	Enhanced Capabilities Required
			Maximise system performance: • Develop all weather capability • Extend Airport Infrastructure • New operational concepts for Aircraft Operators and Airports • Improving landside/ airside processes and design
			CDM
Punctuality: 99% of all flights arriving and departing within 15 minutes of the published timetable, in all weather conditions.		[See 3x capacity challenges]	[See 3x capacity capabilities]
Time spent in airports: no more than 15 minutes in the airport before departure and after arrival for short haul flights, and 30 minutes for long haul.	Time spent in airports: no more than 15 min. in the airport before departure and after arrival for short haul flights, and 30 min. for long haul – excl. discretionary time spent in retail zones (shopping, dining etc..)	See increased airport capacity to handle 3X growth in air movements	
Aircraft will achieve a five-fold reduction in the average accident rate of global operators.	9 x or more safety improvement in consideration of 3x traffic growth (3^2=9)		
Aircraft will drastically reduce the impact of human error.	An Advanced Intelligent System (with its procedures) will drastically reduce human error in Air Transport Operations.	[not analysed in the first pass - WT3 topic]	[not analysed in the first pass]
A seamless Air Traffic Management System mainly based on a civil global satellite system.	Seamless European Global ATM System	[Multi-purpose enablers]	Interoperability within the Air Transport system
			An integrated European Air Transport system
			A common CNS backbone

(2/2)

Contributors

Possible paths to achieve the 2020 goals

Important Note: the first-pass analysis reported here has not assessed in detail the timescales for the R&T developments and the in-service dates that follow. The strategic routes diagrams (Figures 2 through 6) show the various items on a time scaled background that is illustrative only. More precise timing information will be addressed in a subsequent pass. Where items are already subject to ongoing R&T they are shown adjacent to the left-hand edge of the first timescale box (2005). At this stage the likely sequence of developments is of more interest than the precise timing. No attempt has been made yet to consolidate the timing information with other sources.

Introduction: a holistic approach to the air transport system is necessary

The air transport system is a global entity, in which all the different sub-systems need to be considered as an integral part of the global system. Current day practice addresses elements within the system independently: focus is put on the aircraft, the airport or the ATC system without bearing in mind the global picture. It is therefore necessary to consider R&T for more efficient air transport in a holistic manner, be it in terms of scope (airports, ATC infrastructure, Airlines operations are part of a global system), R&T actors *(manufacturers, system providers, operational entities, research centres,…)* or operational actors *(Aircraft operators, ATC service providers, Airport operators,…)*.

As a preamble, the following themes were recurrent to the discussions on how to define a consistent Strategic Research Agenda for air transport:

– Safety as the key to efficiency

It is human nature to believe that "unnatural" activities, like flying, are more dangerous than "natural" ones *(like moving on the ground)*. Hence, the air transport system has been built with an extremely strong notion of safety. Furthermore, the air transport infrastructure capacity is directly constrained by safety objectives set for and by the air transport system itself.

The capacity of an airport or of a control sector is a direct function of how many aircraft a controller or an infrastructure can safely handle. Thus, increasing the efficiency of the system is basically linked to increasing its safety, or the confidence of its actors in the capability of the system to deliver a required level of safety.

Maintaining overall safety levels in the face of three-fold traffic growth means that air transport operations and the supporting systems and infrastructure have to become intrinsically safer as more traffic is handled. A balance between safety gain and capacity gain has consequently to be struck when exploiting system enhancements.

– Incorporating new or non conventional types of traffic

Specific equipment required by new ATM concepts may not make economic sense for non-commercial or "non-conventional" users like Military, General Aviation or Helicopters. R&T must address the procedures for handling mixed traffic, without unduly constraining this section of the aeronautic community.

In the ACARE timeframe, new types of traffic could also play an increasing role in the aeronautical landscape. For instance, it could become necessary to accommodate UAVs[3], thus placing a constraint on how tasks are distributed between ground and air.

Advanced Rotorcraft, such as Tiltrotor which, once converted into airplane mode, fly like a turboprop aircraft, could be used as feeders into congested hubs but this would place specific requirements on the development of the new airports and ATM systems, whilst potentially presenting operational opportunities.

Likewise, airships or, in the longer term, new "personal" air vehicles, could also play an increasing role in the aviation community.

– Transition arrangements: a critical consideration

Transition from the current to the future ATM environment is a very critical process due to long development and validation cycles, the need to achieve human acceptance, high costs for aircraft equipment, difficulty in performing reliable cost benefit analyses, safety demonstration, etc.

Step by step implementation along the strategic routes is probably the only way to progress. Each step must be clearly defined to be manageable, feasible, affordable and beneficial. This does not, however, imply a bottom-up approach to concept definition and longer term goal setting.

Technology demonstrators and pre-operational trials are necessary for assessing the feasibility of each step and confirming the requirements. To follow these, pioneering implementations should be encouraged, in order to ease large-scale validation of solutions and their benefits and to start the implementation process.

3. Unmanned Air Vehicle

– **Institutional and economic aspects**

Whether they are evolutionary or innovative, the new concepts should allow the "users" and other stakeholders to develop in their global competitiveness.

Although long term R&T is less sensitive to economic cycles, necessary investments and business adaptations should be rated in respect to their potential.

Global harmonisation of avionics equipment as well as of some specific airport and crew procedures should be sought through international collaboration and regulatory processes. This may also require specific R&T under the co-ordination of a European institutional body, able to steer European interests.

– **Environment - emissions**

ATM procedures have the potential to reduce aircraft emissions. In the en-route phase of flight, if trajectories can be optimised horizontally and vertically to minimise distance flown and to suit the performance of the aircraft, fuel burn, and the exhaust emissions that result, will be minimised. In the vicinity of airports, fuel-efficient approach and departure paths and procedures, that are well suited to the performance characteristics of the aircraft, will minimise airborne emissions. On the ground, efficient surface movement management combined with apron and gate management will reduce fuel burn during taxiing and while queuing with engines on before take-off and after landing.

– **Security**

In aviation security, the airport landside processes are key. Tightening security raises two issues in this respect:

– Strict security procedures impede the processes that govern the handling of passengers and baggage. This means that airport landside processes may need to be re-organised, in order to accommodate tighter security while still achieving speedy and efficient handling.

– Innovative technical solutions are needed to speed up the security processing and/or to allow it to proceed in the background. These include solutions for the identification of individuals who may pose a security threat; and for the detection of prohibited articles and materials, including weapons and explosives.

The main contributors to meet the Vision 2020 objectives

As shown in Figure 1, four main contributors have been identified and hereafter explained in detail, to meet the Vision 2020 objectives. They are

– Optimising the use of existing ATM-airspace capacity
– Removing ATM-Airspace capacity barriers by increasing inherent ATM-airspace capacity
– Maximising current airports' performance
– Defining the airport of the future
– Creating a seamless Global European ATM System

Considering the strategic routes leading to the creation of new ATM-Airspace capacity, has identified a number of main paths, divided into two groups. The first group addresses the optimised use of existing ATM-Airspace capacity (Figure 2 [4]) and the second group leads directly to the creation of new capacity (Figure 3). The latter would also naturally exploit some or all of the measures indicated in the first group.

R&T challenges and R&T needs for optimising use of existing ATM-Airspace capacity

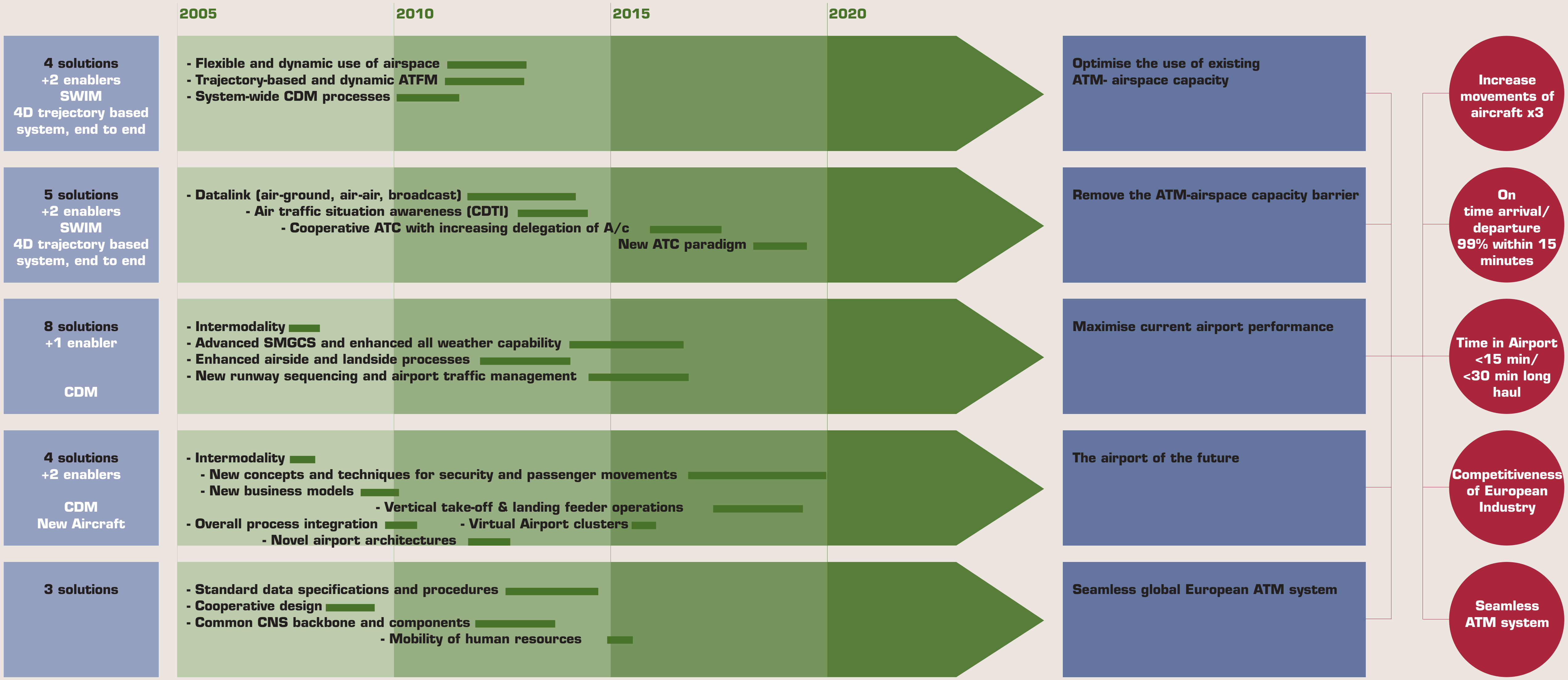
There has been widespread concern for some time that the current sector-based paradigm for ATC is reaching the limit of efficient operation. The primary reason for this results from the need to reduce sector sizes as traffic increases, leading to ever-smaller sectors. This results in a greater proportion of workload being dedicated to communications and hand-over procedures at the same time as reducing the sector transit times for aircraft. Similarly, the lack of available frequencies for ATC precludes the expansion of the current airspace structure into more (smaller) sectors. The effect of this diminishing efficiency has been referred to as the 'Capacity Wall'. Opinion is divided as to exactly when the capacity wall will be reached. However, the likelihood that it will occur within the ACARE timeframe is such that a means needs to be found to break through it. In the meantime, however, there are a number of measures that can potentially increase the utilisation of the existing capacity while longer-term solutions are being prepared.

Paths leading to optimisation of existing capacity include:

– Increasing air-ground co-operation to optimise trajectories and bring the aircraft more closely into the ATC control loop. Optimisation requires moving the whole system onto a 4D trajectory basis. Data link technologies and applications are also crucial. Considerable development is already moving into this area and further R&T is required.

4. More detailed grpahical analysis can be found in appendix 1

Figure 1
Schematic of the challenge of Air Traffic System Efficiency



– Integrating Air Traffic Flow Management (ATFM) with ATC and developing pro-active (Dynamic) ATFM. The foundation of the enhancement is to base ATFM on 4D-trajectory information in order to best use the "close to reality" behaviour of each a/c and thus be more exact in planning and managing the traffic flows. Along the same lines, moving much of the de-confliction planning to a 'traffic management' function operating on a wider area or multi-sector basis would fill in the gap between current ATFM and ATC. This topic is considered as a quantum step in capability thus requiring R&T. This path has already been partially investigated.

– Developing of the Collaborative Decision Making processes. Although there are already pilot projects, many issues remain to be investigated. These range from subjects such as database inter-operability to defining standardised information and decision-making processes. The main challenge of the CDM approach is to enable the migration from a Flight Management System to an Operational Management System, where ATM, Airports and Airspace Users act collaboratively as synchronised elements of the Air Transport System.

– Taking measures to circumvent the limits of human cognition and mental processing power while keeping the controller in the loop and retaining the current basic operational paradigm. When comparing the work of airline pilots and air traffic controllers it is clear that pilots are managing their flights at a much more supervisory level than controllers. Many routine pilot activities are now supported by advanced avionics. This is not so much the case for controllers. Introducing advanced ATC support tools will allow controllers to move to a higher level of involvement, thereby allowing them to handle more traffic. There are a number of existing R&T activities that are addressing these measures for the short and medium term, that may need to be reinforced to address transition to the later stages of system evolution.

– Defining dynamic sectorisation (in the resource management sense) leading to a more flexible and dynamic use of airspace. An approach that has been proposed is to have a much more dynamic way of re-sectorising the airspace according to short term workload and traffic evolution. This effectively relies on re-distributing resources to deal with the real traffic situation. This path is currently in the start of its implementation phase but research is still needed to identify how far this approach can deal with handling 3 times or more than the present traffic.

With more supporting functions taking place in automated systems rather than in human brains, the use of these functions and their information can be differently distributed amongst the human staff. The role of planning positions, in particular, could be significantly upgraded in this way. In the medium term, this potentially opens the way to transitioning to a new operating paradigm. Further R&T is needed to assess the potential and the optimum migration path.

R&T challenges and R&T needs for removing the ATM-airspace capacity barrier by increasing the inherent ATM-Airspace capacity

A number of potential directions for change are foreseen that could lead to an increase of inherent ATM-airspace capacity in the medium and longer term. They are non-exclusive and - to some extent - are likely to be stepping stones facilitating each other, while building on the stepping stones outlined above for optimising the use of existing ATM-airspace capacity.

Potential solutions include:

– More advanced automation to be introduced to replace tasks currently performed by humans. The feasibility of introducing fully automated functions in ground systems, leading possibly to a fully-automated solution in the future, requires investigation. This issue has been frequently discussed but has never been resolved. There is considerable scope for further research to determine how far automation can be taken, especially in relation to fallback modes of operating in a high capacity system.

– Delegation of separation responsibility to the aircrew, potentially leading to fully autonomous flights becoming the main operating mode with consequent reduction in the required ground based services and infrastructure. This could initially be limited to specific circumstances but eventually be performed throughout the whole flight. This option would rely to a large extent on advanced automation in the cockpit. Regarding autonomous aircraft operations, opinions are currently divided as to whether the capacity breakthrough can be achieved by this means. This is an approach that is considered by a number of people and organisations to be the capacity-generating solution for the future, while many others consider it not to be feasible in core European airspace. This option can neither be ruled out or ruled in at this time. Further research is needed to assess realistic feasibility, especially in dense traffic conditions.

– A radical new ground-based ATC paradigm that avoids the constraints of the current sector-based paradigm. A concept is needed to either reverse the trend such that sector sizes can be increased or to get away from conventional sectorisation altogether. A number of more radical concepts have also been put forward and have been studied to a limited extent only, although they offer interesting potential.

A fundamental change option would be to move away from the current ATC paradigm that divides the airspace into a number of controlled volumes (sectors), whereby a controller or a controller team is responsible for controlling all flights passing through the sector and only there. Under the classical paradigm, the trajectory of each aircraft is effectively chopped up into ever decreasing portions of a few minutes duration (in busy airspace) which are each managed by a different control sector. Under the new paradigms, each flight would be controlled for a much longer portion of its trajectory by a single controller or control team, and, at the extreme, this could be for the full trajectory.

- One possibility is to allocate airspace dynamically to aircraft trajectories (instead of to control sectors). This could work with or without sectorisation and offers interesting transition possibilities. R&T questions, still to be resolved, include: the best way to develop this into a full-system concept, the required level of automation and the best approach to address the migration path. Another proposal is to control aircraft by group of flights; typically a group would comprise aircraft following broadly similar routings. Such a concept, which has analogies in certain types of military and oceanic control, would lead to some interesting possibilities. This proposal merits some serious research, since - if basic feasibility could be established - it opens the door to a number of variant concepts.

- One derivative would be to control all traffic from the destination airport or airport cluster (from the point of take-off or soon after) until arrival at the gate at the destination. This would reduce the need for separate en-route control, and focus on the most difficult traffic management situation: the convergence and synchronisation of incoming traffic streams approaching an airport or TMA. Research would need to assess the potentially significant gains that could be made in capacity and punctuality, and the savings that could be made compared to the current En-route service costs.

- Getting away from the airspace volume-based control technologies would enable consideration of completely new business approaches to ATM, by which, for instance, the infrastructure services (CNS) on the one hand, as well as the ATM services on the other hand, could be provided from end to end by a single entity.

Many or all of these scenarios would maintain the trend towards co-operative ATM and could also be combined with a greater or lesser extent of autonomous aircraft operations or delegation of responsibility. Research would need to establish the most feasible and beneficial mix for given traffic situations.

Migration to any new concept is a major issue and transition to these new concepts might be accomplished by gradually converting parts of the airspace, perhaps one FIR by one FIR, to the new mode of operating. From the aircraft perspective, in many instances (excluding equipage for self separation and fully autonomous operations) the changes would be mainly procedural. Research would need to establish the optimum migration path.

These numerous concept options comprise alternate strategic routes. The necessary R&T to determine the best concept or combination of concepts to meet the operational needs of the 2020 timeframe is nowhere near completion at this time, and is certainly not at the point where final decisions can be taken, despite the relative urgency. Some of the key decision points have been indicated on the accompanying Strategic Routes diagram (Figure 3).

Common Enablers

4D Trajectory-based operations

In order to support the different paths shown in Figures 2 and 3, a common, essential step is to develop a 4D Trajectory based system (end-to-end), which would support many paths. Actors that would be providers and/or users of the 4D trajectory information would be ATC, aircraft, ATFM, airports and aircraft operators, military and even meteo services. A fair amount of R&T has already dealt with the provision and use of 4D trajectory information for specific purposes but many detailed issues remain to be resolved and further R&T is need, especially into the question of how to get the whole system working with 4D information from end-to-end.

This capability in turn places a strong requirement on **System Wide Information Management**, in which the information would be consistent, up to date and accessible to all actors. Research should be conducted in order to investigate the communications infrastructure needs and the common definitions that would be necessary for SWIM.

R&T challenges and R&T needs to maximise airport system performance

Airport capacity is likely to be the main limiting factor in the growth of air traffic, in the sense that it is constrained by the physical infrastructure and the building of new airports and airport extensions is subject to restrictive and planning constraints in most countries.

Figure 2
Optimising the use of existing ATM-airspace capacity

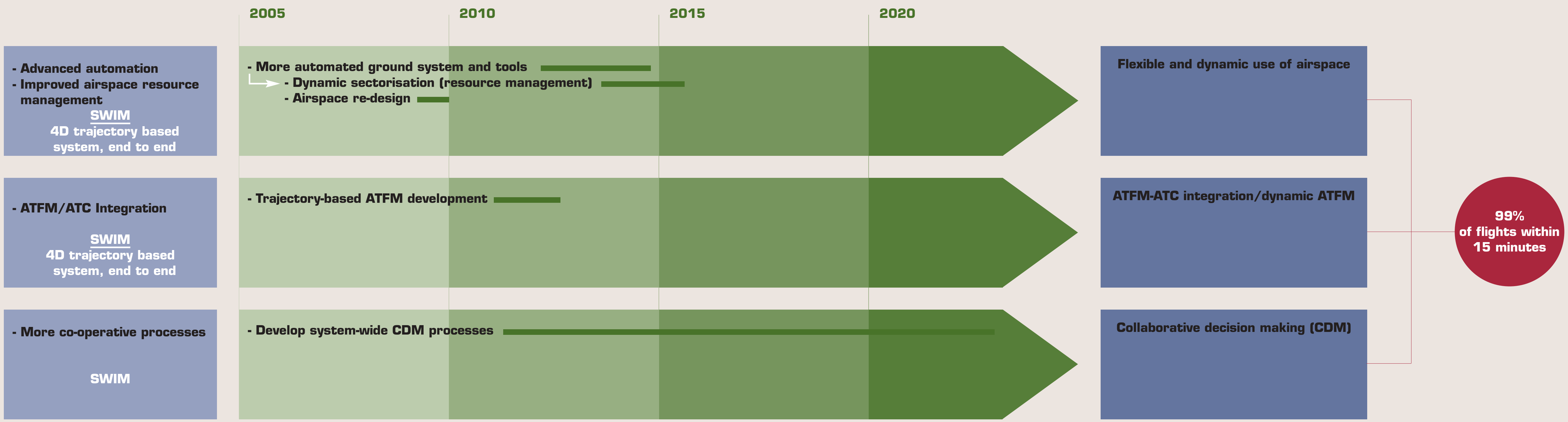
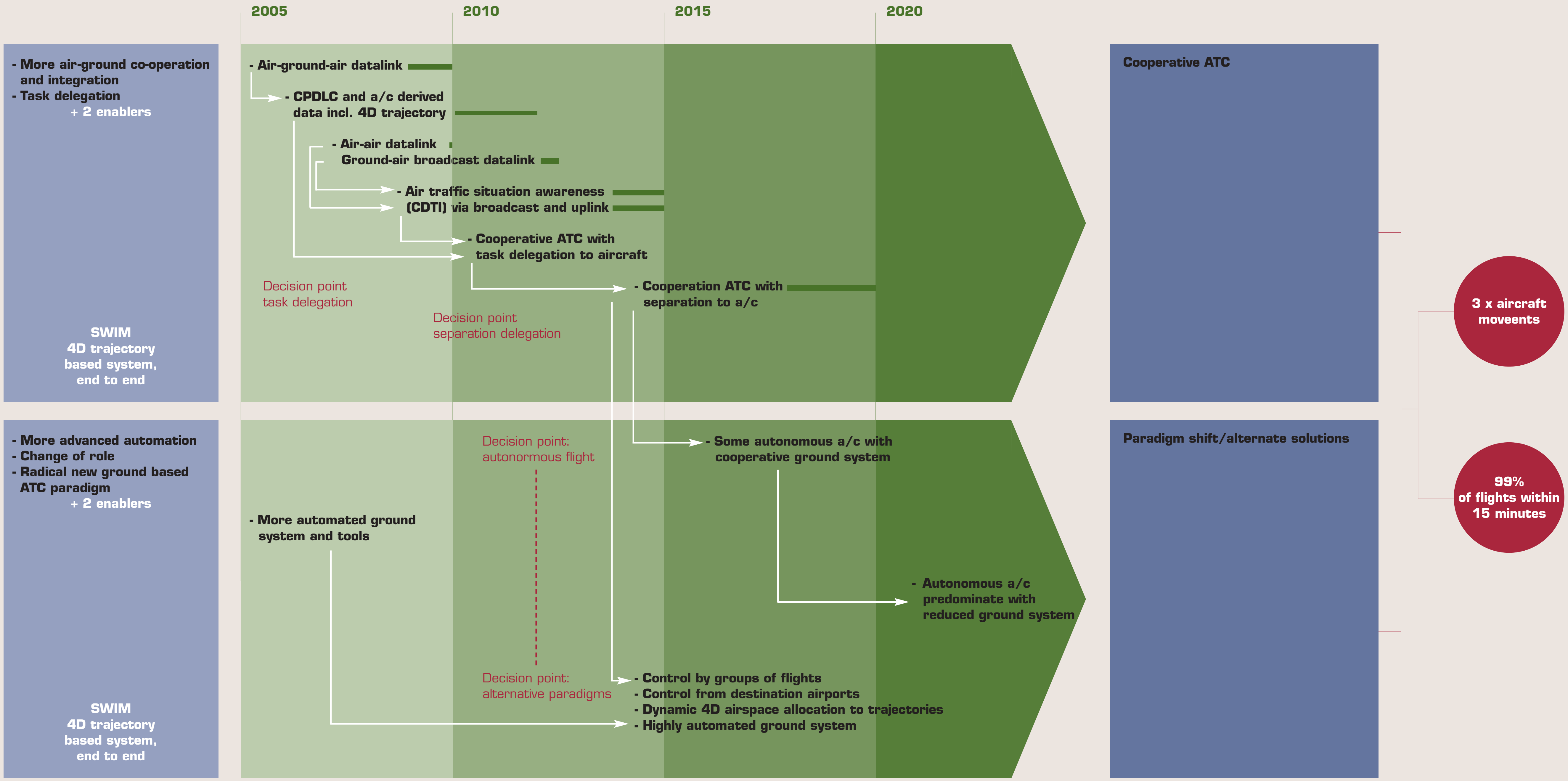


Figure 3
Removing the ATM-airspace capacity barrier



Four main paths, shown in Figure 4[6], have been identified that can lead to improved capacity within the existing infrastructure:

– improve the efficiency of runway utilisation through a number of potential measures

– maintain sustainable capacity in adverse weather conditions, thus minimising the present capacity reductions that occur, e.g. in low visibility conditions.

– improve the efficiency of the airport's performance as a system by improving landside and airside processes and introducing new operational concepts.

– extend the airport infrastructure.

A further possibility is to increase the hours of operation of congested airports but this is highly dependent on advances in aircraft noise reduction and is subject to restrictive planning constraints at most major airports.

Improving Runway performance

Efficient runway usage has long been a subject of research and steady improvement has been made at many airports, to the point where over 50 movements per hour can be achieved for a single runway. However such performance is affected by numerous factors, such as traffic distribution, human perception, equipment availability, regulations, environmental restrictions, etc.

Improving runway utilisation essentially means reducing separation in approach, at departure and on the runway itself. Significant changes to present separation standards will be dependent on: better ways to cope with wake vortex issues, improved collaboration between controllers and crews, harmonised rules, processes and designs, etc.

Further optimisation is also envisaged in the interactive sequencing of trajectories of arriving and departing flights in order to better utilise the runway resource.

Landing aid systems and procedures that can support new types of approach (e.g. curved and steep approaches) and specific approaches for different types of aircraft are all on the agenda.

Likewise the performance requirements of such complex system increase, the human (controller, manager, operator,...) will need "on line" assisting decisional tools that only R&T can develop.

However, it seems most unlikely that the capacity of individual runways can be increased three-fold, while achieving the safety targets. Additional runways are therefore going to be needed and/or transfer of flights to runways at presently under-utilised airports. A business model would have to be defined in order to show how feasible from an operational, technical and economic point of view, operations could be distributed between different airports.

Adverse Weather Capabilities

Whenever adverse weather conditions occur, the airport efficiency is degraded. Heavy rain, strong winds, icing conditions and low visibility are all implicated here. Improvements in meteorological forecasting will help to improve all-weather capability.

Increasing low visibility capacity at airports implies improvements to the landing aid systems so runways can operate at near to maximum capacity in VMC, Cat 1, 2 and 3 conditions, without the present low visibility restrictions.

Low visibility capability also means an improvement in the ability of the aircraft (and airport vehicles) to see and be seen in conditions of poor visibility. A-SMGC systems with all-weather surveillance/ guidance/planning/control capabilities are essential in order to be able to operate in low visibility.

Special weather phenomena and strong wind conditions can also have a critical effect since they require increased separation between aircraft, and also because they often require the airport to use a secondary runway system providing less capacity. In particular, icing conditions can have a serious impact on airport capacity and processes. Adequate prediction and decision-support tools could minimise the ATM system instability created in such circumstances.

These are all areas that are already relatively well researched although new ideas for further improvements are strongly needed before poor-weather capacity can be brought closer to the good-weather capacity level.

Improving System Performance

One line of research is to safely increase the ability to have simultaneous operations on closely spaced parallel runways, crossing and converging runways as well as on rotorcraft landing areas, in good as well as in bad weather conditions.

Dual and triple runway configurations do not normally achieve equivalent multiples in the number of movements they can sustain, compared to a single runway, typically because they cannot be operated fully independently one from each other. However, it has been demonstrated that technology could significantly improve the airport throughput. The capacity gain of such procedure development, according to US experiences and results, ranks around 20%, particularly when it allows the use of an already existing runway simultaneously with others.

Better synchronisation of flights using the runways requires further progress in integrating airport and en-route/TMA ATC and co-ordination of ATC with airport operations. CDM will also play a role for improvement. This "system concept" also applies to airport clusters where, for instance, a single TMA contains several runway systems.

5. More detailed grpahical analysis can be found in annex 2

It is noted that achieving significant progress in some of these areas may mean some modification of the principle of first-come, first-served under certain circumstances so as to act in the interests of the whole traffic. This is inevitably a controversial subject.

Without having to make dramatic changes in current airport architecture, a significant increase in the overall airport performance can be achieved by improving the passenger/luggage handling processes.

Among the items that need to be addressed, it is recognised that the airport processes are lacking common standards and procedures. This results in effort duplication and inefficiencies due to the fact that users have to adapt themselves to the local procedures and tools and there is duplication of process and system development. Standardised, consistent airport processes are therefore viewed as a key enabler for more efficiency.

Adequate consideration of PRM (Persons with Reduced Mobility) cannot be underestimated in the landside processes and designs in achieving the improvement of the system as a whole.

All these process improvements will reach maximum efficiency through close co-ordination between all stakeholders and with optimised movement planning and management, both supported by CDM.

Within airport boundaries, the aprons, taxiways, high-speed turnoff design, allocations and regulations remain inadequately addressed. Operational research could assist in achieving a significant improvement in this area as well.

Another concept for investigation is the idea of "rotorcraft/ VTOL[7]" areas and of "fast track" runways dedicated to certain types of aircraft operations.

Today, some 70% of delays are caused by factors other than infrastructure congestion. These delays can be attributable to: technical problems in the preparation of aircraft; weather problems; deficiencies in the passenger or luggage process channels; and to the ripple effect, by which a delayed incoming aircraft is not able to recover and catch up its delay during the turn around process.

In addition to the improvement possibilities described in the previous paragraphs, new business and operational approaches in the manner of operating the airports need to be investigated.

Research topics include: airport layout and design, underground terminal facilities for instance, new "hub & spoke" philosophy, including the possibility of operating clusters of airports as if they comprised a single virtual airport, etc.

Another question relates to the behaviour of airports, airlines and ATM in their day-to-day business operations. This is tied also to the distribution of passengers between airports, and is affected by market forces and passenger decision making (about modes of travel and choice of airport/carrier) that may not be fully understood.

Other questions include: airport capacity re-distribution between airports (e.g. to smaller airports) or between transport modes (e.g. inter-modality issues).

A separate question surrounds the economic and operational feasibility of using rotorcraft (helicopter, tilt-rotor) as feeders into hub airports where small aircraft runway operations are discouraged.

It is noted that a number of these topics are wider than the technical and operational regimes and require considerations on business economics, competition, regulation, passenger behaviour and stakeholder behaviour.

Extension of existing Airport Infrastructure

There are physical limits to the capacity that can be extracted from the existing airports infrastructure by means of optimisation. The infrastructure of congested airports will inevitably need to be extended if the target of three times capacity growth is to be achieved. Extensions include: additional runways and terminals, additional gates and stands, new taxiways, extended aprons and parking areas, landing areas for VTOL craft and new cargo facilitates. In some cases new airports will need to be constructed, either as additional airports or as replacements for those airports that can no longer be used in the face of economic, operational or environmental constraints. In such cases, the measures discussed under the heading 'Airport of the Future' will need to be considered.

However, to a large extent, the extension of airport infrastructure is more a matter of planning permission and regulation than a topic for research. In support of planning applications and public enquiries there will be nevertheless a real need:

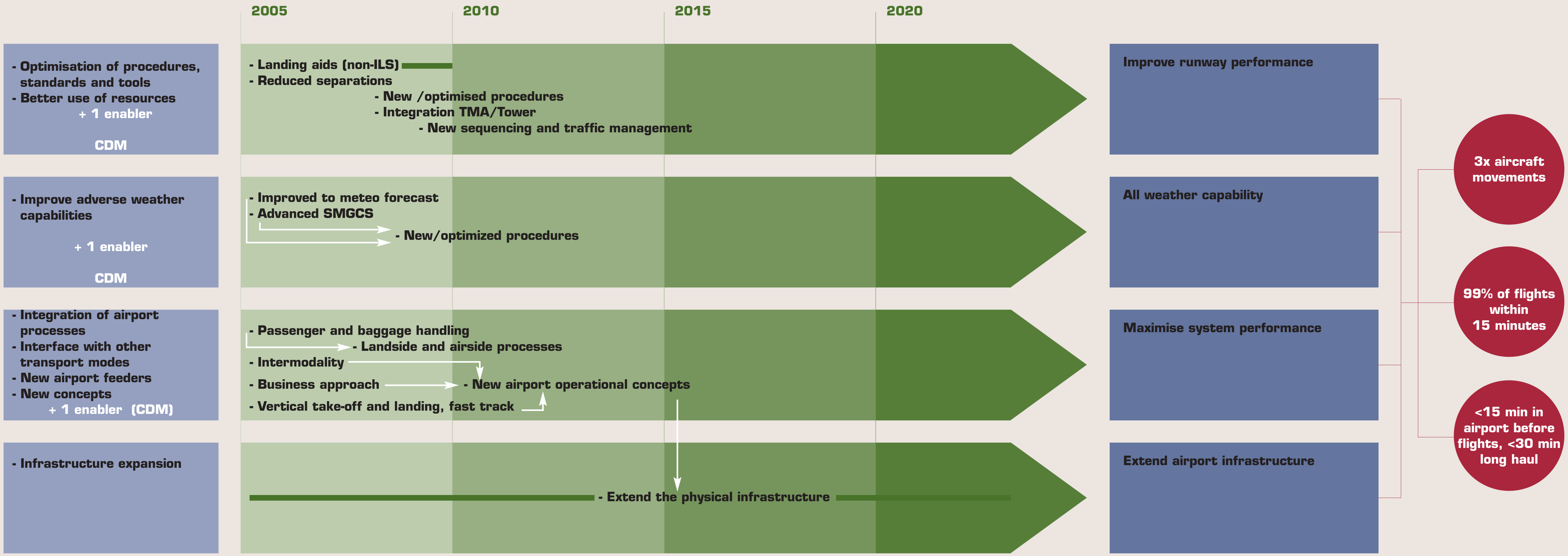
– to demonstrate how the noise nuisance and environmental impact on local communities must be reduced or kept within acceptable bounds.

– to assess the positive impact brought by a performing airport system to the local and regional economy.

There is also a need for societal studies investigating the evolution of aviation perception in general, and airport safety, economy and noise issues in particular, with the goal of identifying ways of ameliorating unduly negative perceptions that hinder the development of aviation. In particular, one has to look into the "capacity-efficiency-safety-environment" equilibrium, as it is likely that increasing one of these items may result in decreasing one of the others. Within Strategic Research lays the opportunity to address this topic in a pragmatic, societal and non- controversial manner, in order to find and try "win-win" solutions.

6. (VTOL : Vertical Take-Off & Landings, i. e. aircraft which does not require runways to operate

Figure 4
Maximising current airport performance



R&T challenges and R&T needs for "The Airport of the future"

Given that there will have to be extensions and additions to the European airport infrastructure if the traffic growth is to be accommodated, there is scope for strategic research along the following paths:

– Innovative landside (passenger, luggage, security …) processes
– Innovative airside operational concepts.
– Overall Integration of processes and operations in a "kerb to kerb" vision.
– Airport of the future" - (airside and landside) designs and architecture.

It must be noted that these research paths, shown in Figure 5 [8] , should be launched in co-ordination with topics addressed in previous paragraphs.

Innovative landside (Passenger , Luggage, security..) processes

The dramatic events of the 11th of September, and the increased security measures for air transport they have induced, show how difficult it can be to reconcile high security requirements and improved passenger and luggage processing efficiency. Given the current average times to have a full security check of passengers and luggage, it is unlikely that the GOP objectives (15 minutes before take off for short haul and 30 minutes for long haul) can be sustained, without a revolutionary change in the techniques used for passenger processing.

Future investigations should address integrated processes for passenger processing, using new technology possibilities such as bio-technologies or micro-chip-based ticketing or boarding documents to enable security related surveillance functions

In the same way, the movement of the passengers in the terminal, between their arrival in the terminal for check-in and boarding the aircraft , would have to be organised in a rapid, smooth and queue-free manner. This would be even more the case if the number of operations and passengers is to be tripled by 2020, the passenger terminal areas would likely be enlarged so as to simultaneously accommodate more passengers and more aircraft.

Related main R&T topics would therefore include:

New concepts and technologies for security checks *(passengers and hand luggage*), including the use of bio-sensors and/or unique travel documents which include all formal identification of the traveller.

New terminal organisation, allowing consistent and fluid passenger processes, enabling passive detection of security threats.

New concepts for passenger movement within a terminal and between the terminal and the aircraft, enabling the above mentioned processes to take place. Under this R&T item, new "people mover vehicles" could be developed, in a manner consistent with a potentially revolutionary new terminal lay out.

Innovative airside operational concepts

In order to reach the Vision 2020 objectives, the arrival of New Large Aircraft, the development of new technologies, procedures and requirements, such as reducing separation standards or installing innovative safety monitoring systems, call for a generic revision of related operational and business concepts. Such revision should be based on all the research proposed above.

Also, the use of VTOL feeder craft, when linked to new specific landing facilities, represent a good potential for capacity improvement in certain circumstances.

Overall integration of airport processes and operations

If the passenger processes need to be dramatically changed, they represent only a part of the complex, multi-actor processes at an airport. Indeed, the performance and efficiency of the global air transport system would also heavily rely on the ability of airports to process flights, that is, aircraft and passengers, in a short time-frame. This could also provide sufficient flexibility so as to minimise the ripple effect of delayed inbound flights.

The airport processes have to be performed with a wide variety of actors, with different cultures, tools and procedures, but they are nevertheless interrelated activities. They would therefore have to be reorganised so as to maximise the efficiency of the whole process, with an integrated, "kerb to kerb" approach.

Standardised airport processes would lead to significant economies of scale and increased interoperability, and were seen as the prerequisite for an integrated airport concept.

A broader instance of integration would be where two or more closely spaced airports are operated as a single virtual airport – something that offers interesting potential where large conurbations are surrounded by a number of airports.

The futuristic airport

The integration of previous researches could help design the shape of "the future airport" architecture, ranking from "underground terminal facilities to offshore airport sites". Some interesting proposals are already being discussed and there is considerable potential for further development in this area.

Airport CDM network: a common enabler

Efficient information management is a key prerequisite in order to allow the actors, including the passengers, to work harmoniously. Indeed, the

8. More detailed grpahical analysis can be found in appendix 3

turn-around process synthesises information on the exact status of the flights coming from the aircraft operator (scheduled time of arrival and departure, crew information), the handling agents (technical preparation of the aircraft, luggage and passengers processing), the airport (assigned gates and baggage carousels), ATC (departure clearance, runway in use, time of arrival), CFMU (ATFM slots constraints) and the Meteorological services. It is therefore an absolute necessity to make sure that all the actors have the best available information at the same time, so that they can organise their own operations in order to provide the best service. It would also be extremely useful to be able to track down the exact status and position of passengers (for example on connecting flights), or to inform them exactly on the status of the flight and on what is required from them.

Research topics would therefore include:

– The implementation of CDM-networks at airports, on which the information would be up to date, of a high quality and accessible to all actors, including individual agents on remote access terminals (eg. PDAs, pagers, mobile phones).
– The development of individual tools to communicate with passengers and to extract real time information on their status and intentions.

R&T challenges and R&T needs for a Seamless Global European ATM System

This goal - defined by the Vision 2020 – includes two very different classes of topics: The European Air Transport System should be able to operate seamlessly, that is, independently of national borders on one hand. On the other hand, there is a considerable amount of efficiency gain from a more integrated system, that is, a seamless system between airports and airspace structures.
They both share the same initiating point: to provide Europe with more and more integrated tools at the European level whilst reducing the obstacle of national borders.

Interoperability within the European Air Transport System

As shown in Figure 6 [9], interoperability applies both to human and machines, in the context of procedures, equipment and data.

Standard procedures, even if not a research item per se, are a key prerequisite for economies of scale and increased efficiency of the Air transport system. Labour mobility within Europe is seen as a foundation for the future of the industry. Societal, and sociological studies should be undertaken so as to define the ways by which labour mobility could be achieved within the Air transport system socio-circles. Until now, they have been mostly confined within national borders (except for the transnational, mutilinational-by-nature Air Traffic Control centres like Maastricht).

Interoperability between operational systems is a key to seamless operations. It is also a key to an increased safety of aviation. Wider than the European air transport operations, interoperability and standardisation issues have to be seen from a global, world-wide perspective. Hence, the aircraft operators will need to have global procedures and systems, so as to minimise the specificity of particular regions they are operating in. From a wider perspective, global interoperability and standardisation are also a factor for an increased competitiveness of the European industry in the world-wide market.

An integrated European Air transport system

The European Air Transport has to be approached in a holistic manner, not only from a geographical point of view, but also integrating its different components into a global vision. Hence, one recognises now that airports are nodes of the system, and that their landside operations have to be considered in their interactions with the other nodes of the system. Similarly, Aircraft operations centres are a node of the system, and their own objectives, procedures and constraints are an integral part of the system.

The holistic approach would lead to the notion of common resources used for different nodes of the system, which would be independent of non-operational constraints. For instance, terminal area control centres could be regrouped into trans-national, regional centres.

This approach would also need an integrated or co-operative industrial approach to the design of the new systems: co-operation between aircraft manufacturers and ground systems suppliers, also between airspace, airports and aircraft operator's process designers.

Enabler: a common Communication, Navigation and Surveillance backbone

For the European system to be seamless, it is required to lay its foundations on a robust, seamless technological backbone for its basic infrastructure needs. Moreover, it is necessary to have a clear long term vision which encompasses strategic, long term considerations, instead of focussing on near term solutions which can preclude or even block a further away paradigm shift. The recent decisions on Galileo are a clear example of a strategic choice contributing to a long term vision.

This backbone would have to comply with the following key requirements:

– Communication, Navigation and Surveillance infrastructure should have independent modes of failure.
– Communication, Navigation and Surveillance must be certifiable (qualifiable for the ground parts)
– Its cost has to be competitive.

The backbone could be provided by satellite-based technologies at least for parts of it, provided that satellite technology is proven to be the best economic choice.

9. More detailed grpahical analysis can be found in appendix 4

Figure 5
The airport of the future

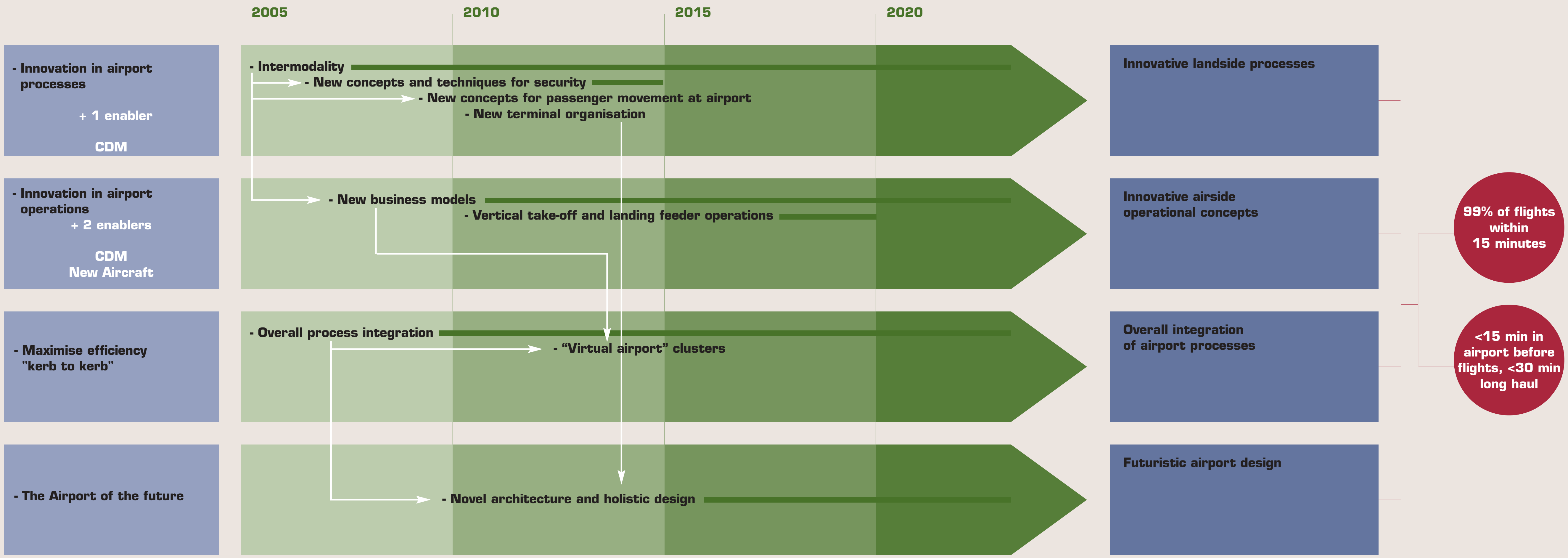
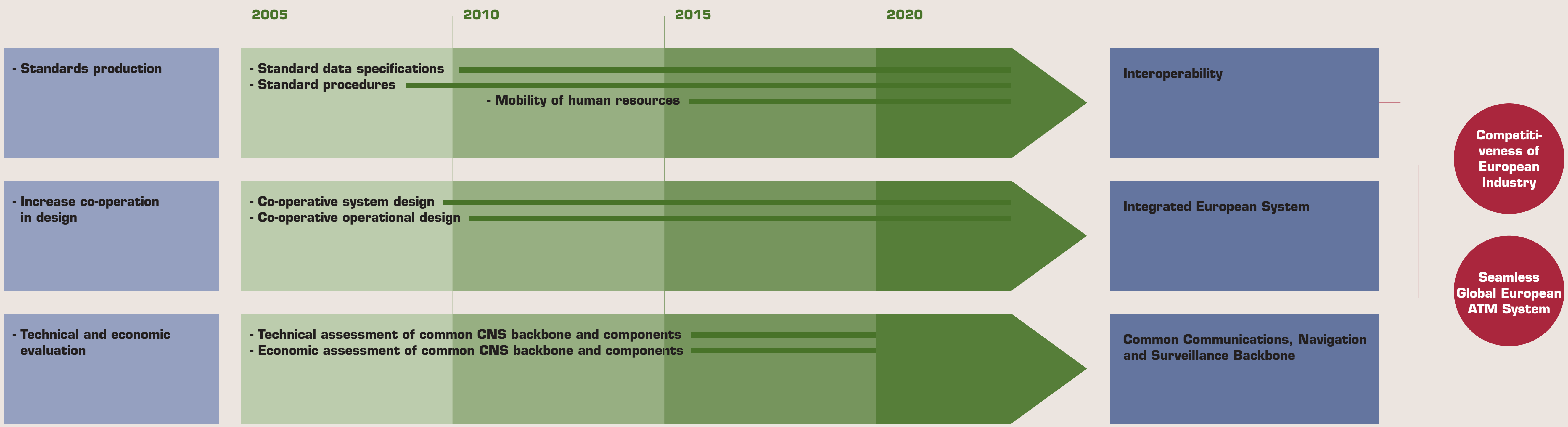


Figure 6
Seamless global European ATM system



Conclusions and recommendations

The Challenge on "Air Transport Efficiency" was analysed by a multinational team of experts, representing all the stakeholders of the air transport industry (manufacturers, air traffic service providers, aircraft and airport operators, Eurocontrol,...). The team unanimously recognised the need for a quantum leap to be taken, in order for the Vision 2020 goals to be achieved.

This quantum leap was deemed to be feasible if a number of pre-requisites were observed, among which:

- *A new approach to airports operations*, which would take into account sociological and economic, as well as technical and operational aspects

- *A paradigm shift* in the operational concept by which the air Traffic system is operated

- *Technology readiness*, in particular for enabling infrastructure such as seamless telecommunication, navigation and surveillance, and in support of the new concepts

- *A holistic approach*, which not only embraces the air transport system as a whole, but also is forward looking and relies on long term investment rather than on (only) short term measures.

The latter was seen as particularly important. In effect, the next steps to be taken need to address the overall consistency of R&T major avenues, in order to make sure that all the components of the air transport system of the future will be compatible with each other. One of the most striking examples could be the R&T path recommended under the "Quality and Affordability" challenge for a single pilot cockpit or even a fully automated freighter, which have to be fully considered in the study of roles and tasks sharing between the air traffic controller and the aircraft. Similarly, the airport of the future needs to be designed so as to optimise the use of new generation air vehicles.

Future work will also define more precisely the different milestones along the SRA, and propose prioritisation and decision making rules. It will also define and encompass transition issues between the current and future air transport system.

Glossary

AATT	Advanced Air Transport Technologies
A/C	Aircraft
AOC	Airline Operational Communications
APC	Airline Passenger Communications
ARDEP	Analysis of R&D in Eurocontrol Programmes
ASMGCS	Advanced Surface Movement Guidance and Control System
ATC	Air Traffic Control
ATM	Air Traffic Management
ATFM	Air Traffic Flow Management
CDM	Collaborative Decision Making
CDTI	Cockpit Display of Traffic Information
GoP	Group of Personalities responsible for the Vision 2020 document
CFMU	Central Flow Management Unit
CNS	Communications, Navigation and Surveillance
CPDLC	Controller Pilot Data Link Communication
FIR	Flight Information Region
GNSS	Global Navigation Satellite System
ILS	Instrument Landing System
PDA	Personal Digital Assistant
PRM	Persons with Reduced Mobility
R&T	Research and Technology refers to developing new technologies – more specifically it covers basic research, concepts, technology development and technology integration & validation
R&D	Research and Development – this includes R&T but also the development of new products
SRA	Strategic Research Agenda
SWIM	System Wide Information System
TMA	Terminal Manoeuvring Area
UAV	Unmanned Airborne Vehicle
VAMS	Virtual Airspace Modelling Simulator
VMC	Visual Meteorological Conditions
VTOL	Vertical Take-Off and Landing
4D	Four dimensions (including time)

Annex 1

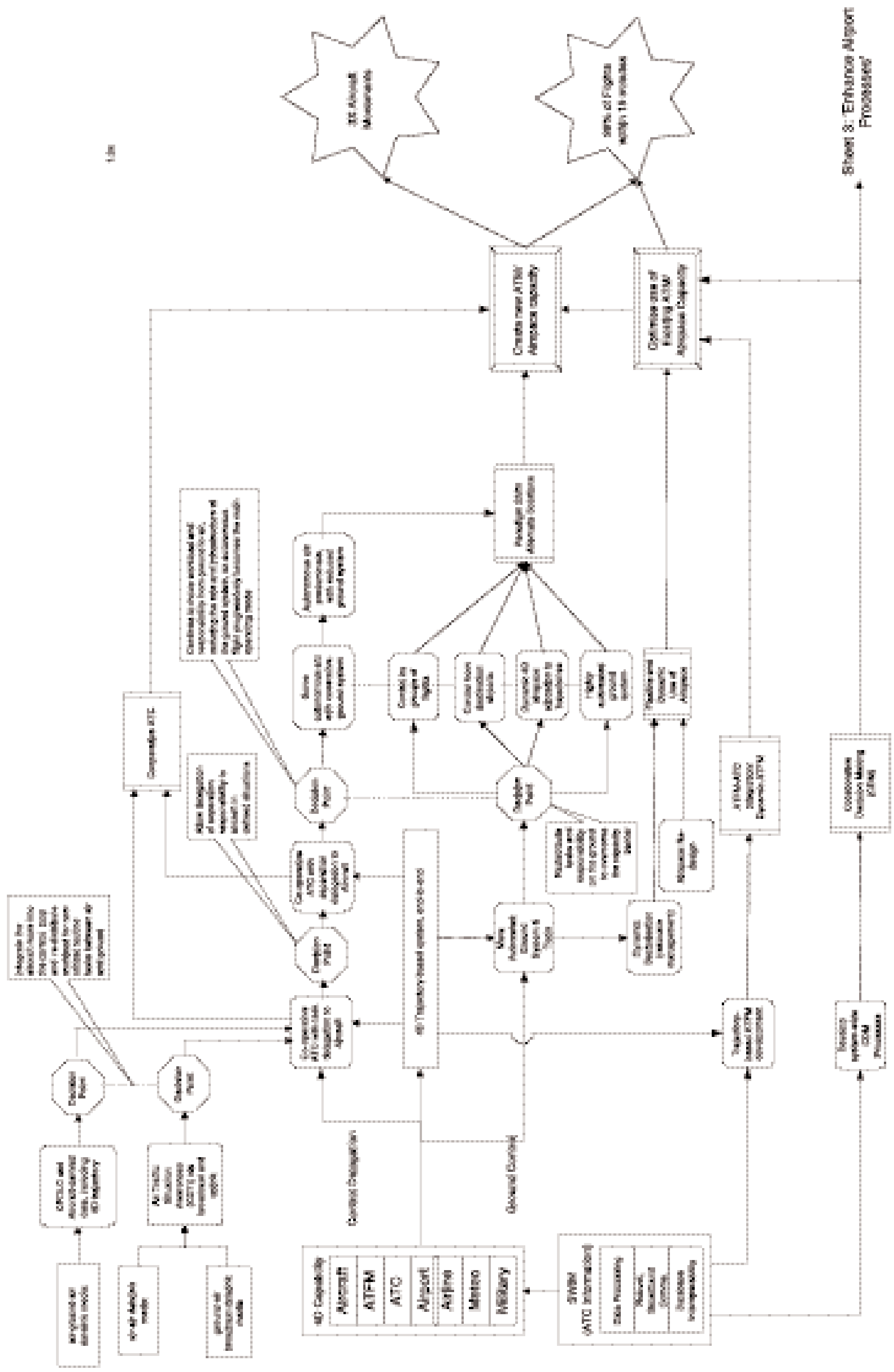


Figure A1 : Removing the ATM-airspace capacity barrier

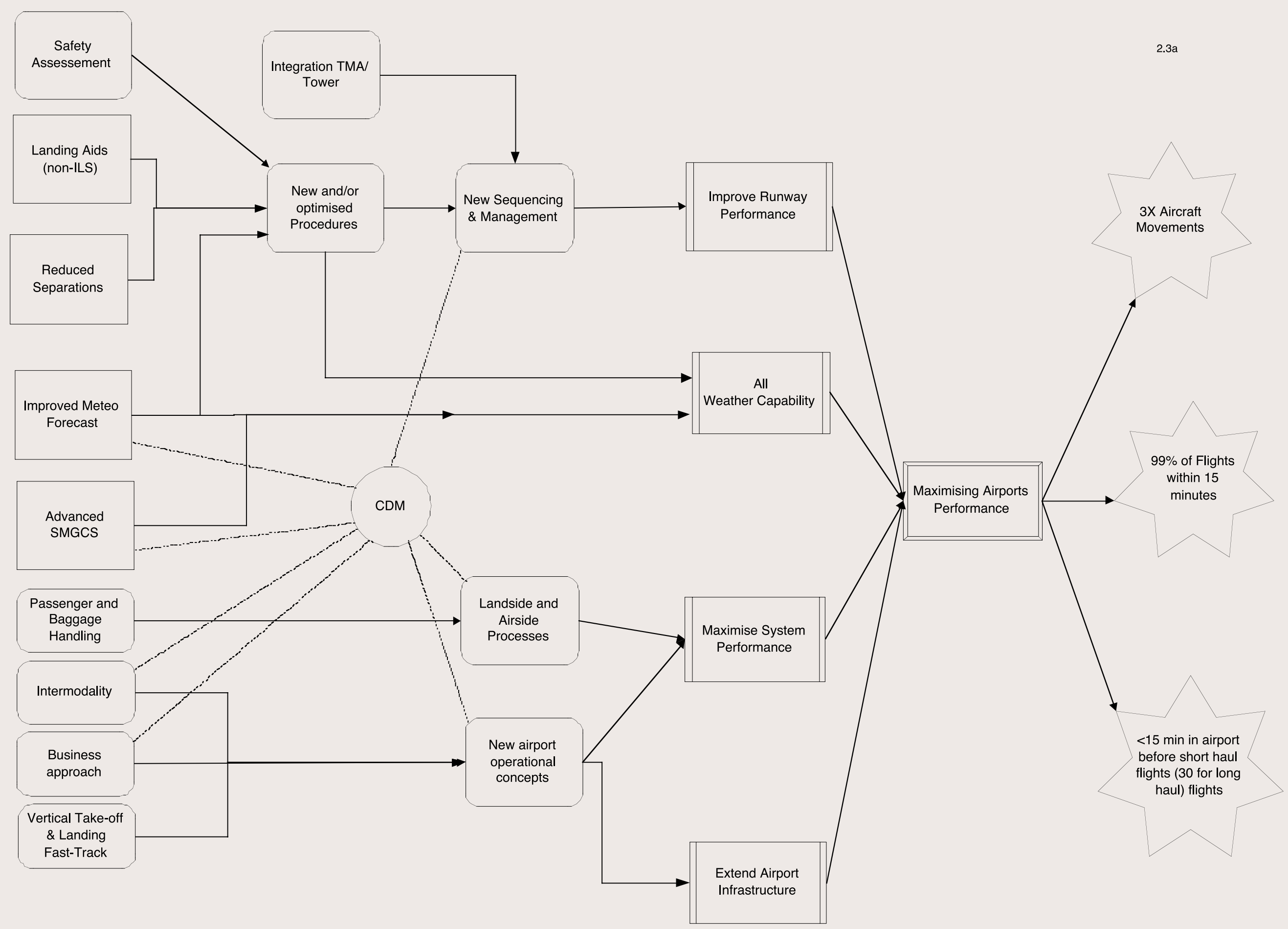


Figure A2 : Maximising airport system performance

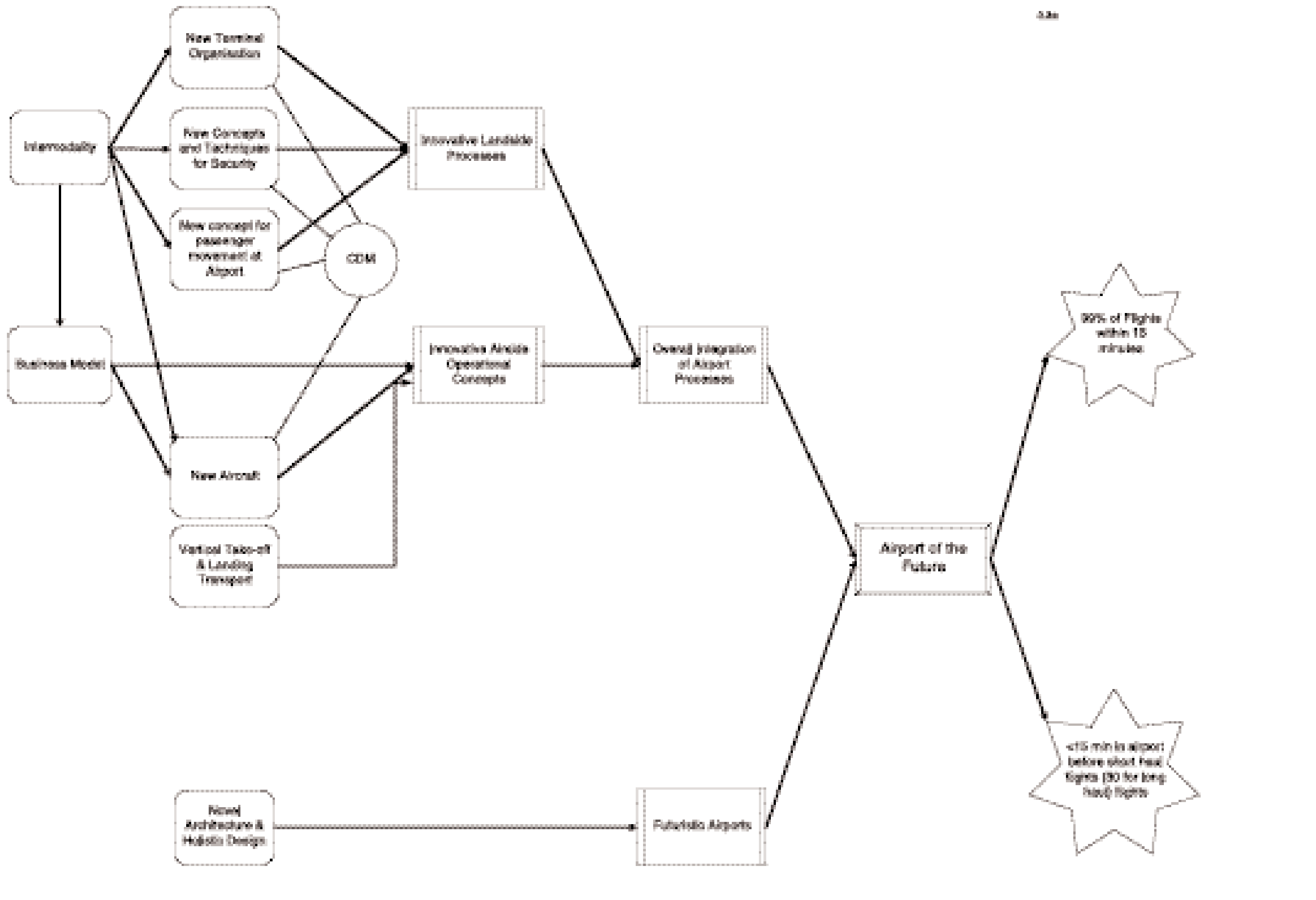


Figure A3 : The airport of the future

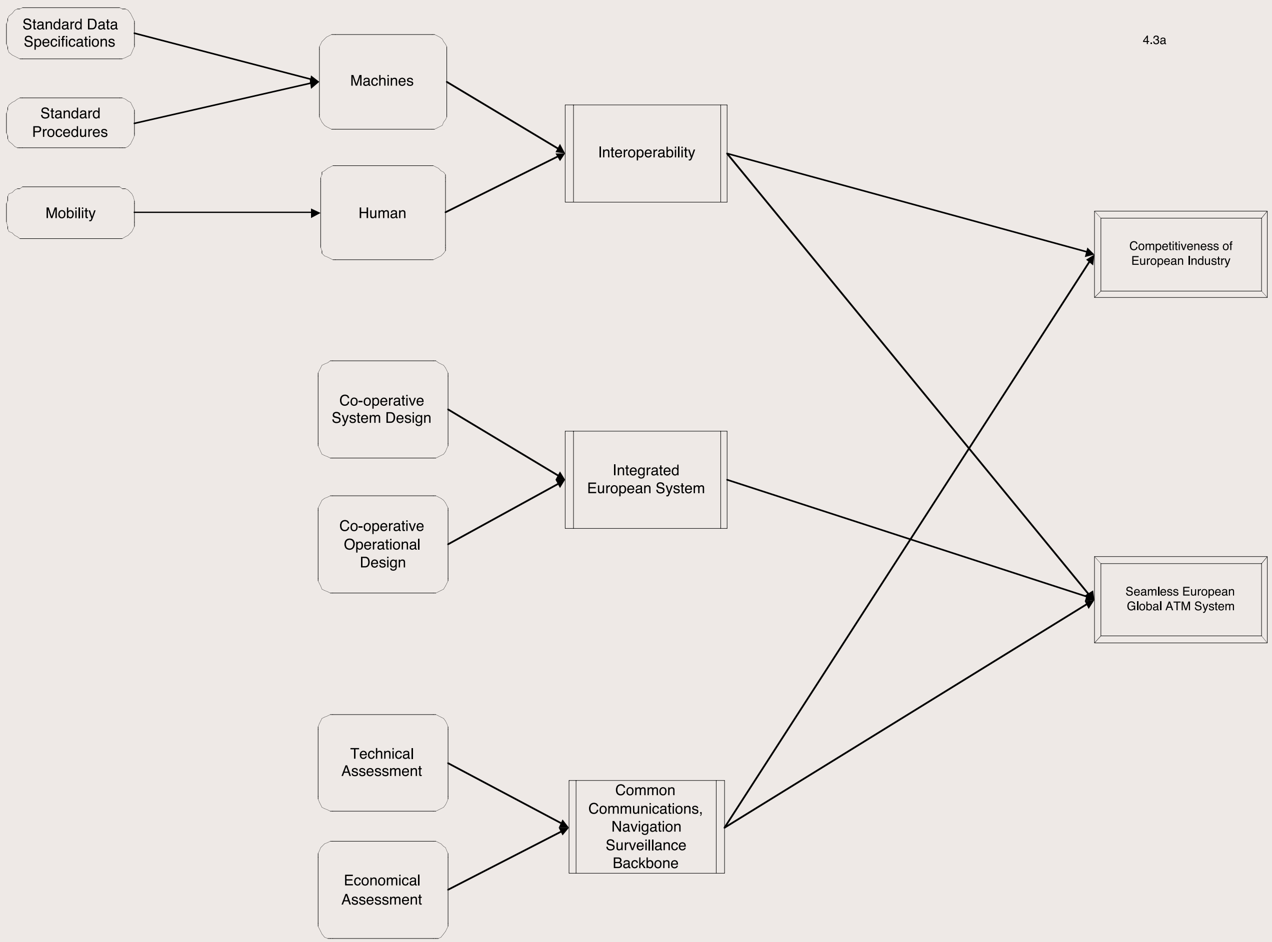


Figure A4 : Seamless global European ATM system