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Out OF THE boX

IDEAS ABOUT THE FUTURE OF AIR TRANSPORT

Part 2

REPORT

November 2007

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EUROPEAN COMMISSION

Out Of The Box

Ideas about the future of air transport

Part 2

Edited by T. Truman and A. de Graaff

November 2007

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1. Executive Summary

Due to concern over the progress of innovation in air transport, the European Commission funded the Out of the Box project to identify potential new concepts and technologies for future air transport. The project focused on a number of radical changes to the system rather than taking incremental steps.

During the first part of the project, 100 ideas were generated. These are described in part1of the report. The ideas were then assessed in a workshop event during the second part of the project and the most promising ones were then developed further.

> **'As a result of the Out of the Box project, a systematic approach was developed to stimulate radical and novel ideas for air transport.'**

The assessment resulted in six promising ideas, covering alternative propulsion, Global ATS, the cruiser/feeder type of long range transport, ground assisted take-off and landing, personal air travel and advanced systems for airports.

The technological content of these concepts were then reviewed and identified. The results were supplied to the European Commission so that some of the technological issues could be incorporated into the work programme of the Seventh Framework Programme (FP7).

A consequence of looking far into the future for radical solutions is that some may take a long time to come to fruition. Therefore, some type of incubator mechanism should be set up within Europe to help such fundamental knowledge develop. The FP7 is one possible mechanism that could provide this incubator environment. It is hoped that universities and research establishments will understand the importance of the development of ground-breaking technologies and will join forces to enable them to be realised.

As a result of the Out of the Box project, a systematic approach was developed to stimulate radical and novel ideas for air transport. Future workshops and in-house research by European air transport stakeholders could lead to additional ideas that, once assessed, could provide additional opportunities to support and develop new ideas for the air transport system of the future.

2 Introduction to Out of the Box

2.1 The initiation of Out of the Box

The concept behind Out of the Box goes back to the period before the preparation of the Vision 2020 Report by the Group of Personalities. It was conceived that some part of the integrated research agenda that was then being discussed should be devoted to looking towards the longer term and to more radical solutions. The Vision 2020 Report was followed by the establishment of the Advisory Council for Aeronautics Research in Europe, which had the task of publishing the first and second Strategic Research Agendas.

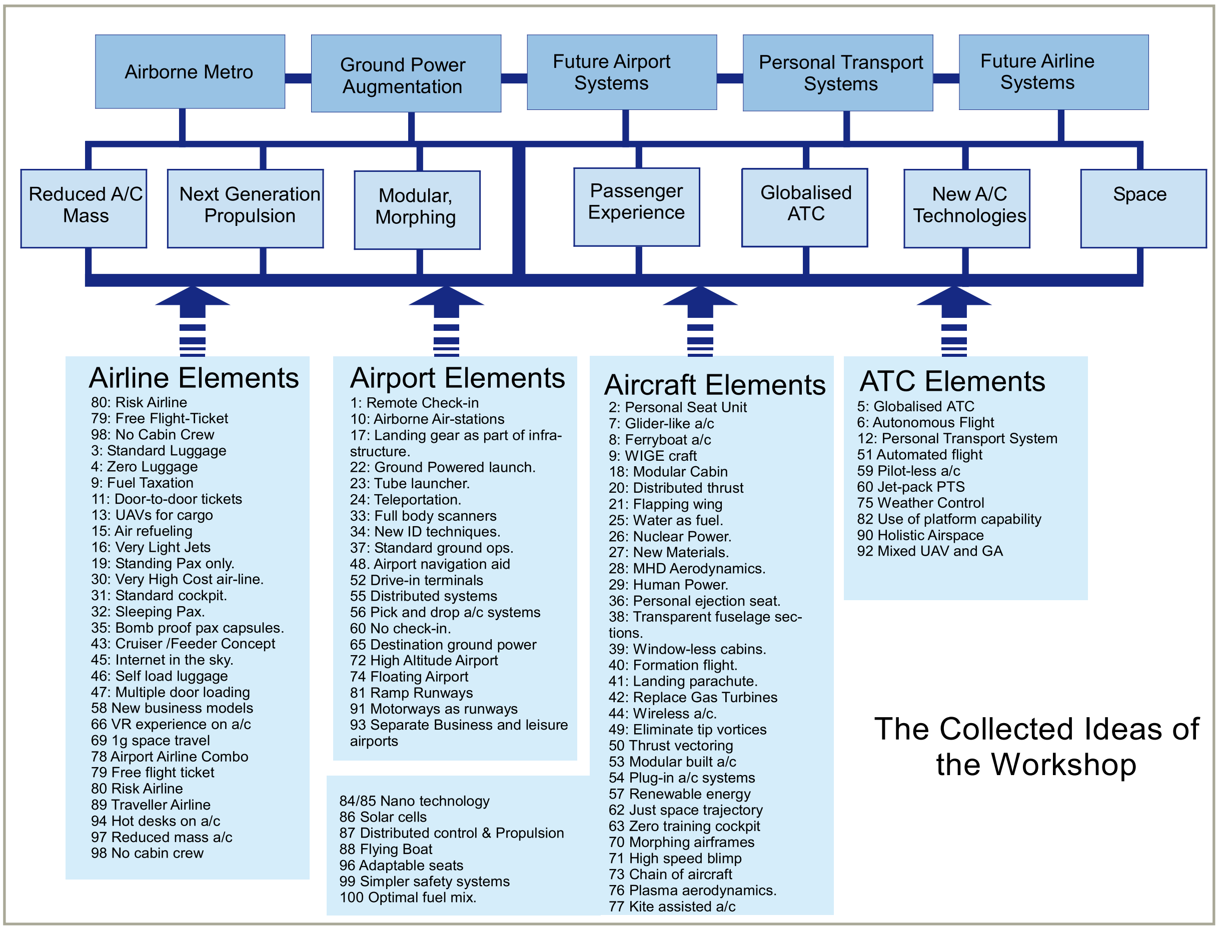
2.1.1 However, during the late 1990s a great deal of work was required to get the integrated concept process moving as well as the main part of the research programme that dealt with more evolutionary and incremental research.

2.1.2 In the spring of 2006, the mainstream development programme was well under way and its extension of the JTI "Clean Sky" was mooted. The European Commission proposed that a limited exercise should be carried out under the auspices of ASTERA, the management support group of ACARE run from the ASD organisation. Proposals were made for a pilot exercise called "Out of the Box" to be run in late 2006 and early 2007. The project was divided into two parts, the first of which was completed in 2006. This involved creative and original thinking, with the first workshop resulting in 100 ideas (Annex B).

2.1.3 The second part of the process concentrated on assessing and developing the ideas produced in Part 1. This was completed in time for a preliminary report to be sent to the European Commission by the summer of 2007. Each part had its own report, with the report for Part 1 being published in late 2006. It was used to help disseminate the concept of Out of the Box thinking both within the aviation community and elsewhere in the transport sector.

2.2 An outline of the concept

The concept of the Out of the Box thinking is fully set out in the Part 1 Report, but for the purposes of reading this report as a self-contained document, it is repeated here in summary.
Aviation is constantly changing. Three factors drive this change: the demands of the market, new technology, and changes in the circumstances of the aviation system.



The Collected Ideas of the Workshop

The first two produce a characteristic "era" of development. Within each era, development continues mainly through the gradual improvement of something that already exists. The leap from one era to another is undertaken in order to meet new and foreseen circumstances for the aviation system. This requires new ways of thinking that cannot wholly be built into pre-existing structures. We can think of this leap, or discontinuity of thought as an innovation threshold. What lies beyond will be new, different and, in some respects at least, unconnected with what went before.

This move to a new era is a result of changing circumstances for aviation services. Today, we see that global warming can become a force for change. Other factors can include segmentation in the market, hydrocarbon fuel availability, a change such as moving towards globalisation and then withdrawing from it, and the pressures of congestion or mass migration. Each of these, either individually or joined with others, has the power to force a change in circumstances and to alter the conditions that govern the air transport system. Such a change would require several new concepts to be available.

Connections with the past will always remain and the laws of physics will continue to impose their strict discipline on what is possible. The infrastructure of the past will take many generations to replace while the human resources involved in the global air transport system cannot be changed overnight and new designs take many years to come to fruition. The system has, in the jargon, both a high inertia and a long time constant. Therefore, the transition to another era is not sudden and rapid but instead evolves gradually.

> 'However, uncertainty is no reason for inactivity. The changes that we can expect will demand new thinking and fresh solutions. If they turn out differently from what we expected, we should still be ready with new solutions.'

Given the inability to make sudden changes, the situation for any new era needs to be considered many years in advance. This should be reflected in the planning and preparation that heralds era major change. These preparations are made more difficult because the circumstances that will apply in, say, 40-60 years' time are themselves uncertain. Several possibilities may present themselves; some may seem more likely than others, but only from our current perspective. How the future will unfold remains unknown.

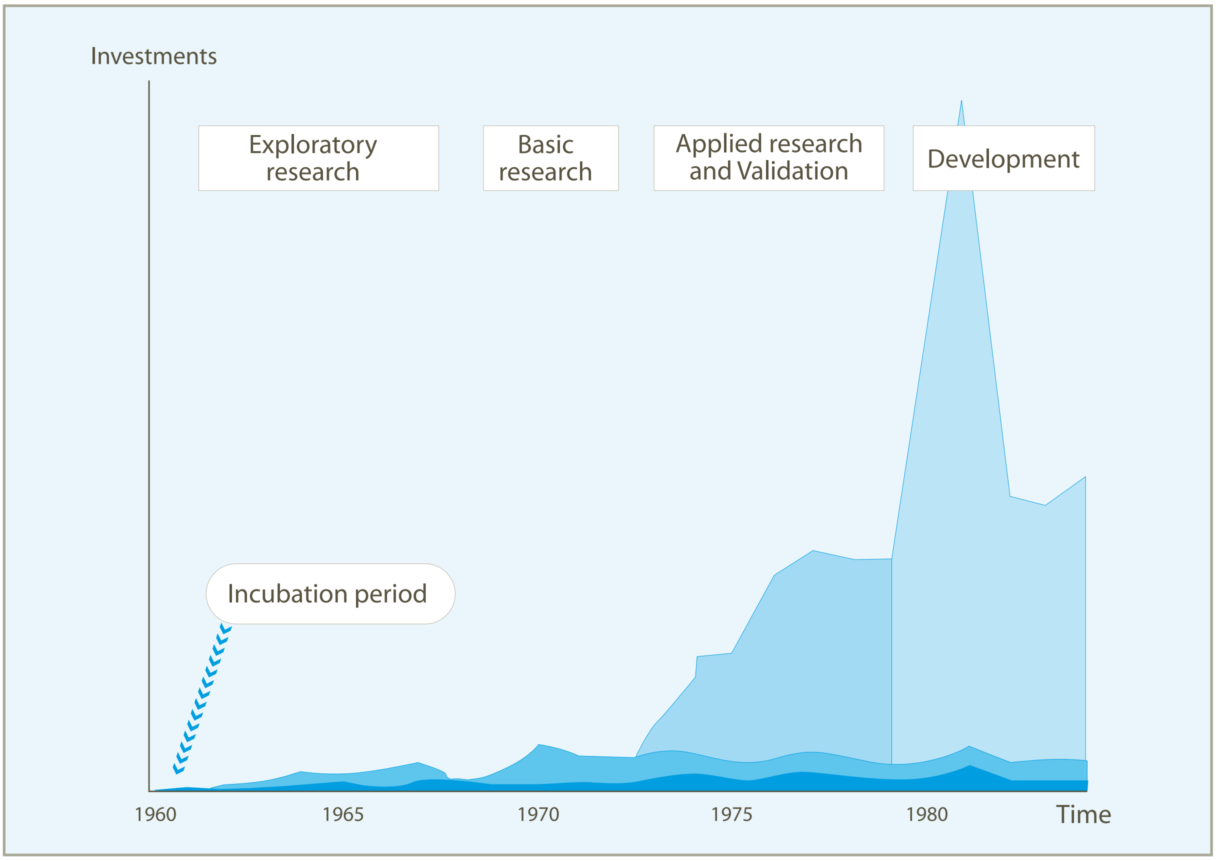
However, uncertainty is no reason for inactivity. The changes that we can expect will demand new thinking and fresh solutions. If they turn out differently from what we expected, we should still be ready with new solutions. This implies being prepared for a number of possibilities and to consider the need for radical change, which will be a feature of the new era. Innovative, one-off, revolutionary and far-reaching solutions need to be considered against possible changes in circumstances. That is what the Out of the Box Project seeks to initiate.

2.3 The process of innovation

To describe innovation as a process may be to risk implying that it is a manageable, regular and consistent activity, which it is not. As a process it is irregular, spasmodic, and chaotic. Nevertheless, innovation can be understood as a way of acquiring new ideas and then working on them until the desired results are achieved.

The process begins with indiscriminately collecting, from any available source, as many ideas as possible for new concepts and innovations. Many, usually most, will fail at an early stage and many more will fail after some work has been put into them. Only a few will make it to the point of providing innovative solutions on the ground and in the air. This is the divergent phase which was reported on in Part 1.

Just like a newborn infant, a new idea can be quickly destroyed by hostility and lack of sustenance before it is capable of fighting for its own survival. Some nursery mechanism is required if the premature death of ideas is to be limited. We can think of this as an “ideas incubator”, which fulfils the same role as for infants, sustaining them while their strength develops. It is a period when a promising idea is guarded from the most violent attacks, particularly on its funding, so that its worth and potential can be properly assessed. Funds do not allow every idea to be protected in this



way and the filtering out of the least promising ones must occur at every stage. Those ideas that survive after a period in the incubator will be re-assessed for their viability in the mainstream of research and then again for their suitability for deployment.

The picture shows the actual development of a supercritical airfoil in the Netherlands in terms of time, funding source and amount of money. The initial incubation period lasted some four years.

This then is a summary of Out of the Box thinking. It emphasises the radical and the innovative, the one-off and the challenging. It is essential to remember that this kind of thinking must always be associated with the more conventional, evolutionary, progressive developments, for these will always absorb most of the effort and funding. Evolutionary development is necessary and desirable; necessary because some things only yield to the steady advances that this approach brings. It is desirable because gradual progression is usually more economic than radical change. The submission of the Out of the Box project is, however, that evolutionary thinking alone is not sufficient and there needs to be a radical element to our research, for it is on these radical and revolutionary ideas that future necessary changes in the concept of operations of aviation will depend.

> **'The submission of the Out of the Box project is, however, that evolutionary thinking alone is not sufficient and there needs to be a radical element to our research, for it is on these radical and revolutionary ideas that future necessary changes in the concept of operations of aviation will depend.'**

3. The Part 2 Task

3.1 The assessment objective

3.1.1 Part 2 of the Out of the Box Project encompassed the convergent processes needed to bring 100 ideas from Workshop 1 down to a manageable number and to select some for recommendation to the European Commission.

> ‘The project was built around a desire to encourage more innovative, radical and far-sighted ideas than were typical of mainstream, evolutionary research.’

3.1.2 The overall objectives of the project were to advise on process experience for this preliminary contract and to make specific recommendations regarding possible incubation. It needed to be recognised that this project had (a) not been carried out before on this scale in Europe and (b) not set out to introduce a complete innovation system. It was important to the European Commission to gain experience from this contract so that a more comprehensive and inclusive system could be considered on the basis of some practical work in the field. At the same time, the Commission wanted to gain specific and direct recommendations from the process that could be used to inject forward-looking initiatives into the Second Call of the Seventh Framework Programme (FP7). However, it was clear from the outset that evolutionary research should continue to be the main effort in FP7 and that the funds available for innovative and forward - looking programmes would be limited. It was necessary to submit only a limited number of recommendations from this project.

3.1.3 The project was built around a desire to encourage more innovative, radical and far-sighted ideas than were typical of mainstream, evolutionary research. It was an inherent intention and there was hope that it would be possible to find some ideas that fitted this implicit model. The team therefore intended, if possible, to submit ideas to the Commission that:

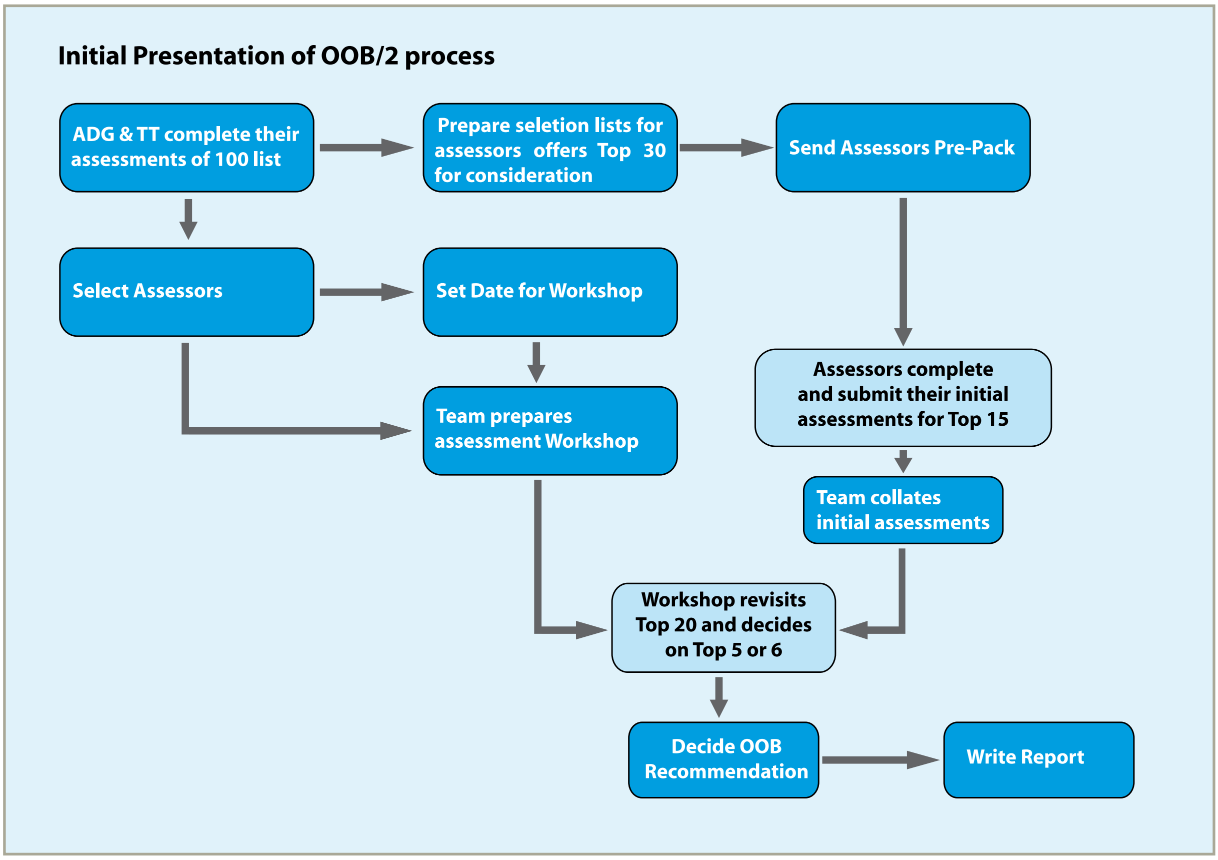
- were radical rather than evolutionary;
- were forward-looking rather than immediate in application;
- had specific technology challenges;
- offered a prospect of significant benefits to the air transport system following the aims of the Strategic Research Objective and Vision 2020;
- offered the prospect of substantial impacts and benefits.

3.1.4 This preliminary list of possible assessment criteria was deliberately left open pending the assembly of a team of assessors who would collectively consider the best way to reduce the 100 ideas to a more manageable number.

3.2 Assessor team

Assessors were invited from within and from outside the aviation community. The final choice of assessors is listed in Annex A.

3.3 The assessable material



Initial Presentation of OOB/2 process

3.3.1 The basic material with which the assessors worked was the 100 ideas from Out Of the Box Part 1. This is reproduced as Annex B. This list was reduced prior to the assessment by a preliminary assessment made by the team of assessors. This assessment was made against a weighted set of criteria:

- Potential Benefits for the Air Transport System (0-5)
- Likelihood of public acceptance (0-5)
- Radical content (0-5)
- Physics credibility (0-3)
- Timescale for incubation (0-4)
- The achievement reached in the incubator (0-4)
- Related and supporting capabilities (0-3)

3.3.2 With this set of criteria, each of the 100 ideas, in its original text, was assessed by the group invited to the workshop. This assessment was carried out before the workshop by each individual. Not all assessments were available at the time of analysis. From a maximum individual score of 29 some ideas scored very highly – one assessor scoring some at 28 points. Others scored very poorly, only achieving ratings of six or seven points. A number of key issues arose from these preliminary assessments.

- Individual markings varied from assessor to assessor with considerable variation.
- The assessors made different choices for the best and worst ideas.
- This resulted in marked variation in the projects most favoured.

It appeared that individual assessor's interpretation of the criteria had had a considerable effect on the scores, as revealed by later discussion.

3.3.3 The 100 ideas were reduced to 23 as a result of this first exercise. This was achieved by first selecting the 10 top scoring ideas from each assessor. These were plotted on a chart and citations recorded for 54 ideas, which was only a modest narrowing of focus. However, some of these ideas had multiple citations and were clearly favoured by a number of assessors. It was decided to select only those ideas that had two or more citations i.e. only taking those ideas that had the most basic of collective support with 2 or more appearances in the top 10 selections of 10 assessors. This reduced the number to 23, which seemed a reasonable number for the assessor group to discuss in their plenary sessions. This list is reproduced in Annex C where the ideas have been re-arranged into the appropriate groupings.

4 The Assessment Workshop

4.1 Objectives

4.1.1 The fundamental objective of Part 2 of the Out of the Box project was to produce specific recommendations for the European Commission, which they could then use to influence the 2nd Call of FP7. These recommendations needed to address the innovative purpose of the project, recognise the structure of FP7 and the need of the Commission to translate the selected concepts into a format capable of being phrased into Calls for Proposals.

4.1.2 Secondary objectives included:

- making recommendations to the Commission about the processes used and their further development;
- reporting to the ACARE community on the results of the project in terms of ideas chosen and recommendations made;
- disseminating the outcome of the whole project to other sectors with an interest in innovative process development.

4.2 Methods of convergence

4.2.1 The initial discussions of the assessor plenary workshop revealed a considerable divergence of opinion. In discussion much of this turned out to be differences of emphasis or interpretation, rather than fundamental differences of position. Language is essential to understanding in these matters and it is a tribute to all those assessors working in a second language that so much progress was made.

4.2.2 To begin with we carried out a simple mapping exercise for the main criteria proposed by the group i.e. technology, meeting society's needs, and improving European competitiveness. This, in turn, raised more issues including the question of weighting. This resulted in a number of alternative weighting and marking schemes being discussed. Some were simply weighted in favour of the more important aspects, while others embodied double marking schemes for relevance and impact. The discussion also raised deeper questions regarding the criteria and what they really meant to convey. As the discussion continued, it became obvious that it was through such debates that the greatest clarity could be achieved. Purely arithmetic marking schemes lost out through differences in interpretation and language; this gave a result that was clearly distorted and so gained little general support. Debate, however, gave each individual the opportunity to articulate their concerns and through discussion to reconcile misunderstandings that would otherwise have been carried over into the marking.

4.3 Discussions of the short list

4.3.1 The outcome of the marking debate was to propose a clarification of the list, as some ideas had close similarities or relationships with others. This discussion resulted in a new short list in which 20 of the original 23 ideas had been incorporated into a new set of 11 newly combined, phrased concepts. This discussion had, in effect, only eliminated 3 of the 23 ideas that it started with. The three ideas eliminated were:

- new materials – on the grounds that much was already being done and the proposal was insufficiently specific at this stage;
- transparent fuselage sections – because this was too limited in its impact and would not have a major social or competitiveness effect;
- remote check-in – because this was more or less embodied in other schemes and in its essential form was already being put into practice.

4.3.2 Despite this limited reduction, the assessors believed that progress had been made although more work was needed on the 11 newly-developed ideas.

4.4 Outcome to Short List B

4.4.1 The resulting short list of 11 concepts comprised the following:

- an examination of new primary energy sources for propulsive power;
- distributed propulsive power and control functions;
- glider-like aircraft with low power consumption;
- formation flight for power reduction;
- connecting the passenger to the aircraft as a process;
- off-shore airports and flying boats;
- door-to-door journey ticketing;
- personal air transport systems;
- global, seamless and autonomous ATS;
- cruiser/feeder concept;
- ground-assisted take-off and landing.

4.5 Discussions of the short list

4.5.1 There was a general discussion about the progress being made. The moderator pointed out to the assessors that they had eliminated very few of the original ideas. What was now needed was for the list to be reduced to a handful of recommendations. To begin with, the assessors found it extremely difficult to eliminate any of the 11 candidates, while at the same time finding it very easy to justify why each of the concepts discussed should be included.

4.5.2 A different tactic was tried in an attempt to force a more decisive result, with the assessors being asked to nominate those concepts least likely to make the short list. This seemed to provide the impetus needed and it was relatively easy to arrive at a final list of six ideas. The process was repeated at each decision in order to force a group consensus regarding the weakest of the remaining candidates for the shortlist. The process sometimes needed to be forced along by the moderator presenting a decision for consideration. The process was not structured, nor was it scientific, but it had the benefit of involving the whole group and served to expand on each of the concepts as one member or another of the group argued the case for or against.

4.5.3 The previous short list of 11 was eventually reduced by 5. The concepts put “below the line” were:

- distributed propulsion and control: The argument in favour was that there was some evidence that distributed propulsion might be more efficient for many smaller engines. This was debated and challenged and it was conceded that multiple engines might be shown to be more efficient, although not for gas turbines where greater size had brought greater, not less, efficiency. The group thought, however, that the geometry of having many small engines would prove a major difficulty since each one needed to be in the air stream to exert its propulsion in a near optimal manner. It was not possible to consider whether this could be achieved with novel propulsion systems from the abstract provided and the idea would need to be more specific before a comparative analysis could be made, trading off engine size against overall effectiveness. The argument against pursuing distributed control seemed to be a little different. Here the case was made that to some degree this was already possible. Developments in control systems and especially in data handling devices would probably require further development and whilst a project could have been defined, the group did not think this would be a suitable candidate for incubation.

- glider-like aircraft: This concept envisaged a major improvement in the fuel consumed per RPK through the greater efficiency of the design and the consumption of much less power. The discussion recognised that aircraft could probably be designed with these attributes although with some major challenges regarding airliner size. The difficulty that a number of assessors had with the concept was that the inevitable reduction of speed would make the economic justification increasingly difficult to justify unless there was a major shift in the economic or environmental cost of fuel. As in all of these short-listed candidates, the assessors believed that a credible project could be defined that would benefit from incubation, but in ranking the project alongside others, it failed to make the final short list.

- formation flight: This had several aspects embedded within it. There was a perceived ATM benefit in dealing with clusters of aircraft rather than individuals. The term "formation flying" was also taken to include both free flying in formation and the ability to dock an aircraft into a cluster. The benefits envisaged would include reduced fuel consumption from the flock or cluster of aircraft. The assessors thought that the docking elements of the idea could be better employed by the cruiser/feeder concept where this aspect would need to be addressed anyway. The free-flight formation flying had several interesting challenges, both technical and operational, but the assessors favoured other projects above this one.

- off-shore airports and flying boats: These two ideas had been combined so that they could be considered together. The argument for this concept was that as populated areas became more densely built-up the land available for airports would become progressively harder to assign. The environmental impact of airports would grow in relative importance as this happened. At the same time, a very large part of the world's population lived relatively near to the sea or to major waterways and this area could be utilised with major environmental and operational benefits. The benefits of using flying boats for freight deliveries to and from dock areas were emphasised. The concept could be extended to one in which major hub airports could be located at sea, not necessarily close to shore. This idea would not involve flying boats as a key element. The assessors discussed this at length and could see that a worthwhile study could be formed around these ideas. However, off-shore airports in littoral waters are already being built and civil engineers could probably build any kind of deep-sea structure that had clear economic drivers. This led the team to place this particular idea below the recommendation line.

- Door-to-Door Journey tickets: The original motivation behind this concept was to allow passengers an integrated choice. In discussion, however, the concept was expanded to include the whole transport sector. In many places, different modes of transport compete with one another but on different terms. The tax and regulation regime was generally not considered for transport as a whole but for each type of transport in isolation. Under these circumstances, the influence of government was dissipated by allowing competition on grounds that did not align with governments' declared ambitions. Door-to-Door tickets were a kind of shorthand for a completely fresh look at the benefits of a more integrated view of transport particularly in those areas where they overlapped, competed or worked in complementary ways. This might lead in due course to an integrated set of "rules" under which individual modes of transport could be encouraged or restricted by encouraging passengers in a different way. This concept was discussed in some depth and it was clear that an interesting and useful project could be defined. However, in the final considerations it failed to reach the final short list.

5

The Selected Projects

The selected projects can be described as follows:

- Aircraft Propulsion: To investigate new approaches and system analyses to the issues attendant upon a possible new primary source of propulsive aircraft power, its provision, use, distribution, etc.
- Globalised and Seamless ATS: A study of the implications, risks, technologies and possibilities of an Air Transport System operating on a global, seamless and autonomous basis.
- Cruiser/Feeder: The concept envisages a series of very large aircraft flying on stable circuitous routes that connect major centers of population in one of several patterns. These large cruisers would remain airborne for very long periods so that they could be considered to be permanently cycling around their designated route.
- The Use of Ground Power Sources: This concept takes as its motivation the reduction in the installed power or installed systems on the aircraft as a means to reduce weight and fuel consumption.
- Personal Air Transport Systems: Ideas exist to enable individual air transport in order to avoid the ever increasing congestion on European roads and to offer an alternative for the current transport system in new European Member States.
- Connecting People with Aircraft: Concerns the system used to process passengers and their baggage from arrival at an airport to being seated in the aircraft ready for departure. The usual experience of the passenger now is to go from one process to another, from check-in to baggage deposit to emigration to security and so on in ways that do not appear to be connected or integrated.

The projects are described in more details below:

5.1 Project 1 – aircraft propulsion after gas turbines (ideas 42 and 43)

5.1.1 This idea was the amalgamation of a number of related topics put forward in Part 1. The ideas centred around two particular aspects of possible future scenarios. Firstly, that fossil fuel costs may continue to rise and make alternative fuels and a significant increase in efficiency imperative and, secondly, that energy sources of a quite different nature might be needed. For both reasons it was thought that a replacement should be sought for the traditional gas turbine in its present advanced form.

5.1.2 The assessors' discussion made it clear that a fundamental view should be taken with regard to the propulsion system. It would be desirable, for example, that energy should make the most efficient and direct transition from fuel to forward motion. Whilst the gas turbine is the most effective solution that we have today, its overall efficiency is only average. The discussion also noted that all energy sources should be considered. Although it was accepted that some would be relatively easy to relegate, it was thought that this was in itself a valuable part of the study. The availability of all the energy supplies examined should also be investigated, as should their delivery and the disposal of any residue. The environmental aspects of different energy sources should also be examined as part of the assessment.

5.1.3 The assessors thought that whilst primary energy sources should be examined, it would also be important to consider hybrid energy systems, possibly working in new ways.

5.1.4 It was not the task of the assessors to come up with solutions to these challenges and, by and large, this was avoided. Nevertheless, during the discussion it became clear that the assessors thought that the research should be ground-breaking and should not address any schemes that were already fully funded. Examples of the latter included fuel cells, and advanced gas turbines, amongst others.

5.1.5 The challenge as formulated by the assessor group was:
'To investigate new approaches and apply system analyses to the issues attendant upon a possible new primary source of propulsive aircraft power, its provision, use, distribution etc'.

Technology Aspects:

5.1.6 A wide range of technologies may be covered by the project. This assessment can only indicate the areas where expertise is most likely to be needed. (This caveat also applies to the other projects examined here).

5.1.7 The study would certainly need a range of aeronautic technologies to deal with the output needs for propulsive power and to reconcile the issues of lift, drag, weight and their dynamic interaction. Basic physical laws are used to consider the transition of energy from one state to another. Conversion means might well involve mechanical and electrical design and the resultant designs would need to be considered for their integration into the aircraft structure.

5.2 Project 2 – globalised and seamless ATS (ideas 5, 6 and13)

5.2.1 During the discussion, the project was provisionally defined as: 'A study of the implications, risks, technologies and possibilities of an air transport system operating on a global, seamless and autonomous basis.'

5.2.2 The future air transport system was expected to benefit from a single seamless management system that would replace the diverse systems presently in use. But the concept also embraced the idea of a high degree of autonomy, allowing individual aircraft to make their own way through the greater part of what we now know as controlled airspace. New systems would be needed for this, along with new boundaries and relationships between the various participants.

5.2.3 This project was intended to go well beyond the work of SESAR (Single European Sky ATM Research) and the assessors considered whether there would be any interaction between them. However, they were clearly of the view that whilst SESAR might produce issues that could be of interest to this project, the opposite would not apply. The time focus of the two projects is also quite different with SESAR concentrating on the next decade or so while this project focuses more on the middle of this century.

5.2.4 The assessors were clear that a comprehensive view should be taken regarding this study. It should address a framework for air transport on a very large scale. The study should consider the whole system when defining its aims and objectives. It was necessary to examine a number of issues and their position within this large scale framework. The key benefits of each issue and the obstacles facing them would need to be examined within a number of scenarios, some of which should include different radical options.

5.2.5 The project was recognised as being a very large concept. This was discussed and the conclusion reached was that this was inevitable if the considerable benefits envisaged for a truly global system were ever to be realised.

5.2.6 There were certain aspects that needed to be defined as part of the study. For example, the discussion revealed some differences in the assessors' understanding of the degree of autonomous operation that should be examined. How should this interact with the latest control methods, how should autonomous operation move to strict control methods and under what circumstances? Could autonomy include totally autonomous vehicles and would this enable unmanned aircraft able to fly safely and securely through air space around the world? These were among the wide range of issues that needed to be examined during the study.

Technology Aspects:

5.2.7 It was observed during the assessors' discussion that tools to help with this study were already well advanced and were expected to improve even further. Modelling and artificial environments could be used to explore different functional relationships and their implications.

5.2.8 Advanced IT technologies need to be used if total autonomy is to be sought. Advanced network-centric networks will need to support a safety overview. Neural network and artificial intelligence will need to be introduced. Advanced display systems are required that should be developed in close affinity, with a human-centred approach.

5.3 Project 3 – the cruiser/feeder concept (ideas 43 and 15)

5.3.1 The cruiser/feeder concept was discussed extensively in Part 1 of the project. During the assessors' discussion, the idea was expanded to include related concepts such as refuelling in mid-air. The idea envisages a series of very large aircraft flying on stable routes that connect major centres of population through one of several circuits. These large cruisers would remain airborne for very long periods so that they could be considered to be permanently circling around their designated route. They would fly at an altitude and speed that was both economical and which would remain fairly constant. Linking these cruisers to fixed bases near centres of population would be a series of short range shuttle aircraft designed only to travel from the ground to the interception point with the cruiser and back again. The feeder airliners would be able to land on or dock with the cruiser for the transfer of passengers and freight. This could be accomplished by individuals moving from one to the other through the transfer of a portable platform, complete with passengers, at the docking station.

5.3.2 The operation of the cruiser feeder system has not been studied in depth but it has been foreseen that with a totally different operational concept, great benefits could be achieved. The environmental impact of the system might be much lower than the present expanded air system. Total fuel consumption could be much less. Passengers might not need to book in advance for a particular feeder aircraft, which could operate on a shuttle basis. Depending upon the frequency of a cruiser route near to one's departure or destination point, it might be possible for an individual to simply join the next available cruiser. This implies that different business models should be considered for the operation of these craft.

5.3.3 As yet, there is no single stable concept that embodies this idea. A number of variations of it are possible and each one presents a different challenge. One of the first tasks for any project studying this idea would be to assemble a structure for managing different conceptual elements that could be combined in a number of different ways. These would then be studied in order to isolate the most feasible alternative scenarios.

5.3.4 A version that might include a nuclear powered cruiser exists, but the issues that would arise from this option have not been studied in depth. The study needs to address how such a cruiser would be launched, how it could be maintained, and what would happen in any kind of credible emergency. All of these questions would need to be considered. The alternative of a non-nuclear cruiser would present almost identical challenges with the need to re-fuel the cruiser in order to maintain its semi-perpetual flight around the world.

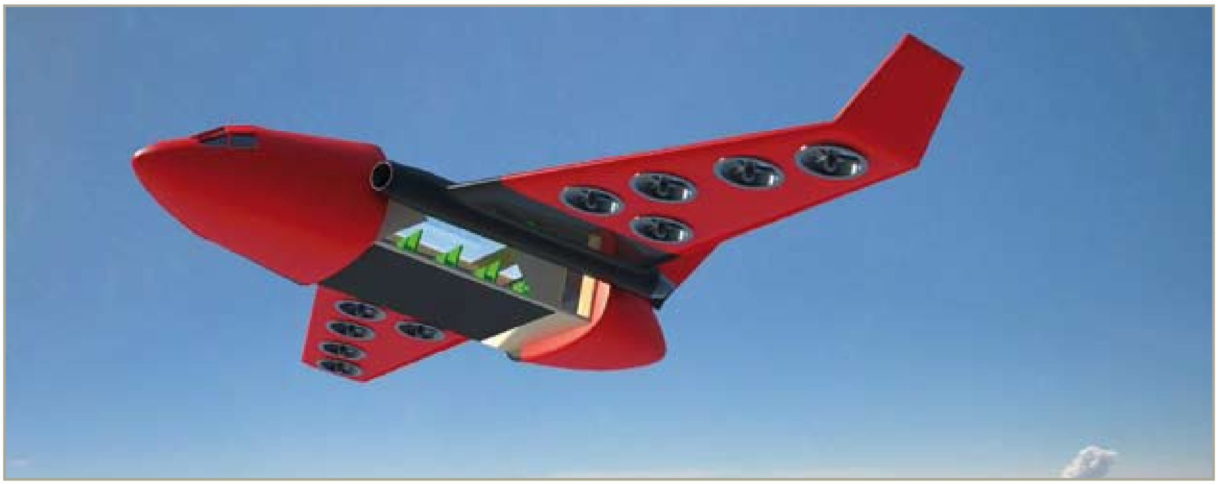
5.3.5 The system aspects of this concept would be the first place to begin and a structured analysis of the system implications would be an early priority. This analysis would point the way to individual issues that would need to be considered separately and then integrated within the concept. Different modes of operation and different hypothetical sizes for the cruisers and feeders need to be studied and the concept developed to a point where the benefits could be considered against the initial optimisation of the concept. The technological issues that this optimised version would raise are likely to be challenging, but should be set against the expected benefits.

Technology Aspects:

5.3.6 The first issue is the design of a suitable cruiser platform. This will be a large aircraft. Total aircraft design will need to be investigated. This relates to the aerodynamics, the structural design, control, power plants etc. A suitable source of power needs to be examined, such as a nuclear engine. Since the 1960s little research has been conducted in this area. The landing and take-off from the platform is another research topic. Wake vortexes behind the mother ship have proven to be a critical factor in all previous designs where docking was attempted.

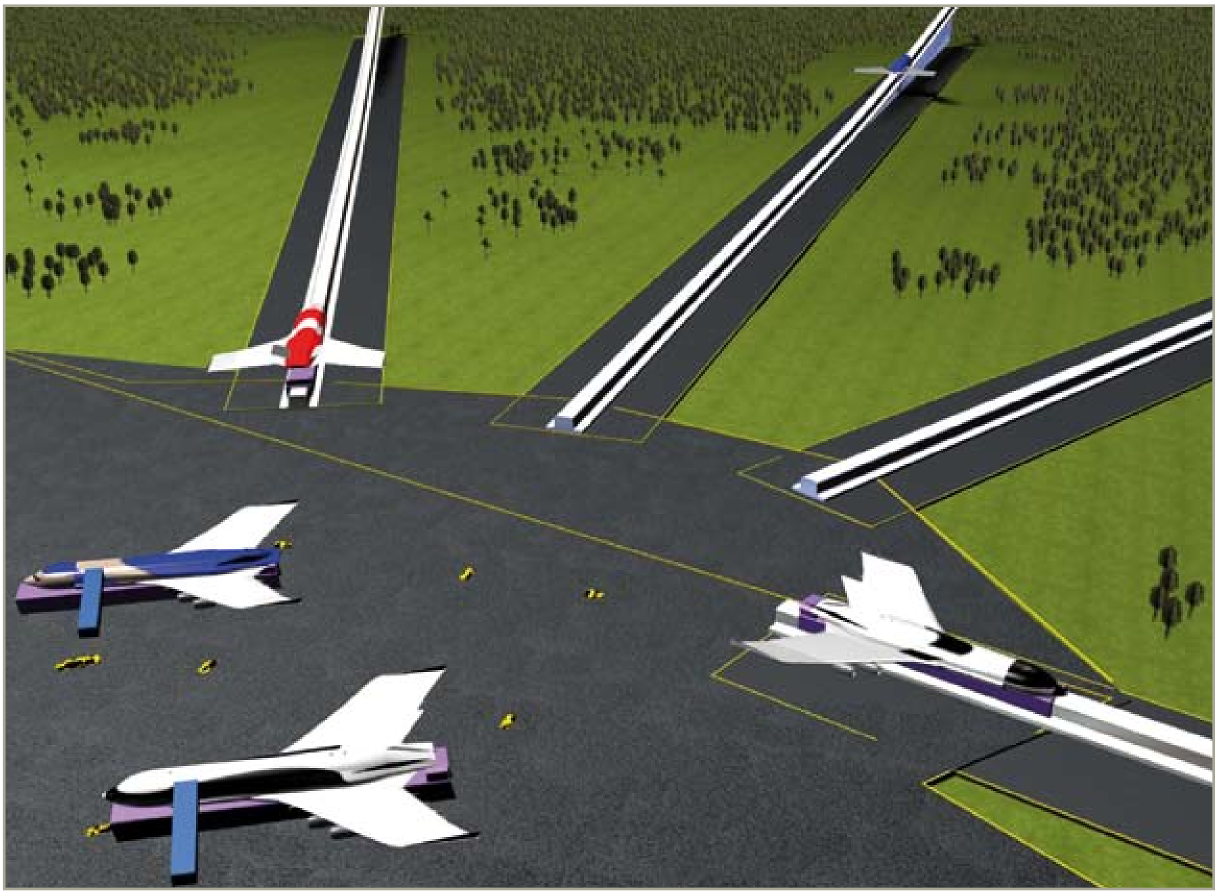
5.3.7 Also the idea of air refuelling needs further consideration. New methods that would be safer and easer to handle than the current system may be developed. Automated refuelling would be sought.

5.3.8 The design of the feeder aircraft also needs to be addressed. This could be an advanced VSTOL aircraft. But to be flexible and provide near door-to-door services, the aircraft would need to be very quiet which is not the case with current VTOL aircraft. New propulsion arrangements also need to be studied. Optimal payload and range will be important parameters. The feasibility of carrying preloaded passenger containers should be investigated. Loading and releasing these containers needs attention.



5.4 Project 4 – the use of ground power sources (ideas 17 and 22)

5.4.1 This concept is motivated by the reduction in the installed power or installed systems on the aircraft as a means to reduce weight and fuel consumption. Other benefits include use of smaller airfields, noise reduction and other environmental gains. The use of ground power begins by taking into account the phase of the flight being considered. Take-off is usually considered to be the easiest phase in which to apply ground power but this might well involve some complementary system upon landing.



Technology Aspects:

5.4.2 For take-off assistance, electrical, steam or magnetic devices could be used. These could rely on oil-based, nuclear or solar energy sources. Energy storage is one issue to be investigated.

5.4.3 In order to launch aircraft ramps, MAGLEV or catapults could be used, that might be augmented by a short burst of rocket power.

5.4.4 Research into aircraft design adaptations, energy requirements plus the safety of the system is required.

5.4.5 With regard to landing, the idea is to reduce aircraft weight by eliminating the undercarriage. Some alternatives to be looked into include landing on water, landing on vehicles that could use electro magnetic fields to position the aircraft, para-foil landings etc.

5.5 Project 5 – a personal air transport system (idea 12)

5.5.1 The idea of personal air transport is not new. In the past, many people have tried to come up with ideas to develop personal transport vehicles. These failed because the technology was not adequately advanced and business models for personal air transport were lacking. In more recent years, NASA has investigated concepts for personal air transport vehicles and their operational environment. This was coupled with a policy to revitalize small aircraft production in the United States. Recently, small aircraft have been developed that can be used as a new form of air transport, creating a new air taxi business. This is completely different from business aviation which is already well established. Many designs are on offer for very light jets, some originating from European companies like Grob and Diamond.

5.5.2 Ideas exist that would allow individual air transport in order to avoid increasing congestion on European roads and to offer an alternative to the current transport system in new European Member States.

'Ideas exist that would allow individual air transport in order to avoid increasing congestion on European roads and to offer an alternative to the current transport system in new European Member States.'

5.5.3 Studies into Personal Air Transport Systems (PATS) inevitably begin with the design of the air vehicle. This has been the case for innumerable designs put forward over the last half century or more. This is not the approach of the Out of the Box team. The first issue that needs careful consideration is the operational concept. Where can individual aircraft take off and land, what is the environmental impact, what about certification, maintenance, training and what about ownership models, liability issues and infrastructure requirements?

5.5.4 We believe that the personal air vehicle can be designed and can be an effective small aircraft. It should present few fundamentally innovative challenges and we are confident that skilled designers have the ability to formulate designs that work well. This is not the reason why PATS have failed to be successfully developed on a commercial basis.

5.5.5 In the assessment sessions, the team discussed the reasons behind why, if the above is true, the concept remained attractive but had failed to be adopted in any serious way. The conclusion was that the concept has some very challenging issues but that these lay in the difficult areas of operating systems, systems engineering, regulation and control and that these areas had not been attractive to the many "inventors" who had come up with air vehicle designs over the years.

5.5.6 It is not hard to understand why this should be so. But the assessment team believes that this important concept should be considered as a major innovative project with the terms outlined for Out of the Box incubation. Basically, this is because the emphasis needs to be placed firmly upon the system aspects of PATS. Whilst it is clearly possible to construct a single small personal aircraft, the challenge of safely operating a large number has not been sufficiently addressed. Assume, for example, that in a city of 1 million people perhaps 2 % of the population might own a PATS and 15 % of these might be in use at any one time. In the extended city area, maybe 30 km2 in size, this might yield an average operating density of these systems of 40 per km3. Addressing the challenges implied by these sorts of figures needs a fundamental examination of the basis of operation, regulation, safety, personal/automatic control, competence and much more. The key problem is not about making a small vehicle fly, but rather how it should be operated.

Technology Aspects:

5.5.7 Consideration of the operating concept will determine starting assumptions about whether PATS should be fully autonomous, guided and controlled by computers, or whether there should be some measure of personal control. Avoiding collisions is clearly one priority but protection against system failures, interference with normal air traffic management, and noise pollution will also need to be considered.

5.5.8 It is likely that the PATS will embody sophisticated electronics but of a commercial form that will also be affordable.

5.6 Project 6 – connecting people with aircraft (ideas 47, 33 and 53)

5.6.1 This concept turned out, after much discussion, to be a composite of a number of different ideas. It concerns the system used to process passengers and their baggage from arrival at an airport to being seated in the aircraft ready for departure. The usual experience of the passenger now is to go from one process to another, from check-in and baggage deposit, to emigration and security and so on in ways that do not appear to be connected or integrated. Queues form and reform at intervals through these multiple processes, and the whole procedure takes a considerable amount time and involves a lot of walking. The assessors considered the issue to be about designing a single process with multiple outcomes. The process would need to recognise a number of constraints and would be required to work in sync with numerous other processes.

5.6.2 There was debate about whether this concept was really one as bland as "The Airport of the Future" and without sufficient specificity to the passenger experience. This was rejected

by the group who distinguished it from any Airport of the Future-type programme by its concentration upon the essential process of the passenger and baggage. The project could not be accomplished in any smaller way unless the outcome was to result in a new form of the fragmented end-to-end addition of processes we have now. Only by enlarging the framework of the study could a new single and integrated process possibly be conceived. Within this there were many challenges. Many of these would involve the integration of subordinate or individual processes in new ways. There would also be new opportunities to be considered if the linear and geographical limitations of the airport could be placed temporarily to one side.

Technology Aspects:

5.6.3 The main focus of the concept studies will need to be systems-based but it is necessary to include considerations such as security, immigration processes, baggage routing and handling, ticketing processes etc. so that these can be fully integrated into the system model.

6. Conclusions

6.1 The overall Out of the Box process

The Out of the Box perspective has very useful benefits. The initiative created an opportunity at a European scale to discuss creative ideas for the future of the air transport system. Participants showed a positive attitude during both workshops. No negative comments were made. Participants also refrained from making negative remarks based on current experience or practice.

Although it was expected that industrial propriety rules would limit the contribution of some participants, the issue proved to be non-existent. Participants gave the impression that they were free to speak and took part in the brainstorming sessions without hesitation.

It was a pity that the airport community was not represented during both workshops despite all the efforts to encourage the sector to participate. However, there now seems to be an increasing interest from the airport community in the results of the first workshop and it is hoped that this will be sufficient to convince the sector to provide delegates to future Out of the Box workshops.

During the first workshop, a limited amount of project money was spent on workshop dinners and cost reimbursement for some participants. The budget for the second part did not allow for such services. Allowance for cost reimbursement in the budget of future workshops is recommended. Cost of travelling and hotels should not be a reason for university representatives and students, for example, not to participate.

The information provided to the participants before both workshops helped to create the correct mindset during the exercise. Although the preparatory actions required a lot of work, the participants were well prepared for the workshops and had the opportunity to generate their own views before getting together.

The workshop needs proper moderation. This should be done by someone who has experience in leading these kinds of activities. The project benefited to a large extent from the experience of Trevor Truman. At the start of each workshop the time schedule, expected outcomes and methodology were explained. This helped to create the right workshop attitude.

During the first workshop a number of parallel sessions were organised. It became clear that registration of the results of these sessions using a standard format recorded on a computer during each session, is of great importance.

During the second workshop, no parallel sessions were required. It is important to record the discussion by creating appropriate computer files. Therefore, duties carried out by a project secretary are essential for a project like this.

It is encouraging that the project results were well received by the European Commission and ASTERA/ACARE. Both plan to use the information in future activities. The experience showed that artistic impressions made for some of the ideas helped to disseminate the project results. Although these pictures are expensive, they do help to get the idea across. We recommend having these kinds of pictures made after any future Out of the Box workshop.

6.2 The Objectives

6.2.1 In the Out of the Box project a number of objectives were formulated. These were mentioned in Annex D of the first report. After concluding the second part of the project, the achievements against the original strategic objectives were:

to bring together knowledgeable representatives of all stakeholders in the air transport system and relevant experts to work together in brainstorming workshops;	Achieved, although the airport sector was not sufficiently represented.
to take a fresh look at the air transport system of tomorrow and identify radical and innovative concepts and solutions for the development of the future systems;	Achieved in Report Phase 1
to contribute new mechanisms by which the air transport system could operate in the future;	Achieved in Report Phase 1
to provide guidance to the European Commission on the contents of the aeronautics and air transport work programme of FP-7;	Achieved in Report Phase 2
to provide a stepping stone for a future European Incubator Organisation;	Achieved in Report Phase 2
to assist the European Commission in disseminating the results of the project to ACARE and its participants, to the ACARE Communications Group and to Air TN via ACARE;	Dissemination accomplished in Phase 2
to increase public awareness about the future directions in air transport and to keep air transport an attractive sector for young people to seek a career in the Air transport sector;	The project helped to guide other initiatives by ACARE
to facilitate the dialogue on air transport issues with third countries.	Planned after Phase 2

6.3 Process Development

Improvements for making the process better, easily repeated, consistent and more easily transferred to others, are discussed below.

6.3.1 It proved to be difficult to interest some organisations or individuals in participating. It required a lot of chasing up to collect names of workshop participants from European stakeholder organisations that are represented in ACARE. Names were provided at a very late stage of preparation of the workshops. This may be partially due to the fact that the Out of the Box activity was the first of its kind at a European level. Therefore it is expected that - now that the first Out of the Box activity is rated as a success - it may become easier to obtain commitment from stakeholders when organising future workshops. Some pressure from ACARE and the European Commission on these stakeholders will certainly help as well. There was a danger that the participants would be too much technology oriented. The participation of people with different background, such as in socio-economics, needs more focus in future workshops. There should also be a good mix between young, creative people and more experienced individuals with an open mind.

6.3.2 Finding the right evaluation assessment criteria during the second workshop was not an easy task. The criteria included political and socio-economic factors, air transport systems, passenger appeal and technical elements. Weighting these elements needed careful consideration, and in this respect the second workshop was a learning experience. Good guidelines need to be provided to the participants at each workshop since future participants will be different from the first Out of the Box project.

6.3.3 Participants should be aware that the aim of the project is not only to come up with creative concepts for the future air transport system but also to identify technological topics that need further attention. Therefore some original business concepts that were discussed during the workshop could not be selected in the final stage of the assessment as the European Commission's Framework Programme is primarily technology oriented.

6.4 Expansion and sustainability

6.4.1 The aim was to extend the process beyond a single project. The idea resulting from the workshop was to create a process for continued creative thinking regarding the future of the air transport system. The process should be more comprehensive than just a workshop and the assessment of the results.

6.4.2 The elements of the process were already identified during the writing of the ACARE Strategic Research Agenda. First, air transport will benefit from creative solutions that are introduced in domains outside aviation. To track these novel solutions a European technology watch activity should be started.

'We foresee the need to continue the creative workshops, involving different people in each workshop activity. As mentioned earlier, participants will not only have a technical background, but be from a variety backgrounds.'

6.4.3 We foresee the need to continue the creative workshops, involving different people in each workshop activity. As mentioned earlier, participants will not only have a technical background, but be from a variety backgrounds.

6.4.4 We need to gather new ideas that are floating around at the air transport stakeholder organisations and combine them with previous ideas. It is proposed that a WIKI type of web page where new ideas can be aired is set up.

6.4.5 All the different ideas need to be assessed in order to fully understand their nature and impact.

6.4.6 An incubator mechanism to help emerging technologies to mature should be developed. Such an incubator would not be a single entity. It would be a virtual network that would guide the growth of new ideas. The actual work can be done in the Framework Programme, in national programmes and at universities, research organisations and industrial labs.

6.4.7 The process is offered for initial funding by the European Commission. If the Commission decides to help by setting up such a process, it can be applied to other modes of transport as a valuable tool for taking an innovative approach to transportation. Already the Out of the Box project results have been noted by the Waterborne community.

7. Recommendations

7.1 The project recommendations for incubation

It was recommended that the European Commission enable the development of relevant technologies related to the six concepts that resulted from the Out of the Box project. In Annex E an indication is given concerning those areas of technology that need attention. Annex E provides an overview based on the ACARE taxonomy for European research.

7.2 Process recommendations

We also recommended the European Commission continue encouraging creative thinking regarding the future of the air transport system.

7.3 Next steps

During the Out of the Box project and in discussions with the European Commission, it became evident that apart from the need to continue annual or bi-annual idea generation workshops and the assessment of the results, other elements needed to be added to the process.

7.3.1 It was recommended that the ideas generated by the Air Transport stakeholders are to be made accessible to the whole European aeronautics community. As a result, the initiation of a WIKI-pedia type of website (Innopedia) is recommended.

7.3.2 Furthermore, it was recommended that a form of European technology watch mechanism is implemented to track technological developments in other sectors. The need for such a mechanism was already identified in the second Strategic Research Agenda of ACARE.

> **'There is a general consensus that some sort of European incubator mechanism needs to exist where novel ideas can mature.'**

7.3.3 It has been observed that there are limited possibilities and a lack of money for high-risk, long-term research at European universities and research organisations. The current trend in the technological infrastructure is to give priority to short-term research and technology development that will generate money at short notice.

7.3.4 There is a general consensus that some sort of European incubator mechanism needs to exist where novel ideas can mature and implementing this concept is recommended. Again, the need was already expressed in the SRA2. Such a European initiative would not by definition require a new organisation. It is quite feasible that better joint directions and an improved organisational setup for cooperation in innovative research would yield good results. Funds could be better aligned and the aeronautics sector could also benefit from the new European Research Council initiative and perhaps use the new European Institute of Technology that has been initiated by the European Commission. Such an incubator initiative would serve the European Research Area initiative of the European Commission.

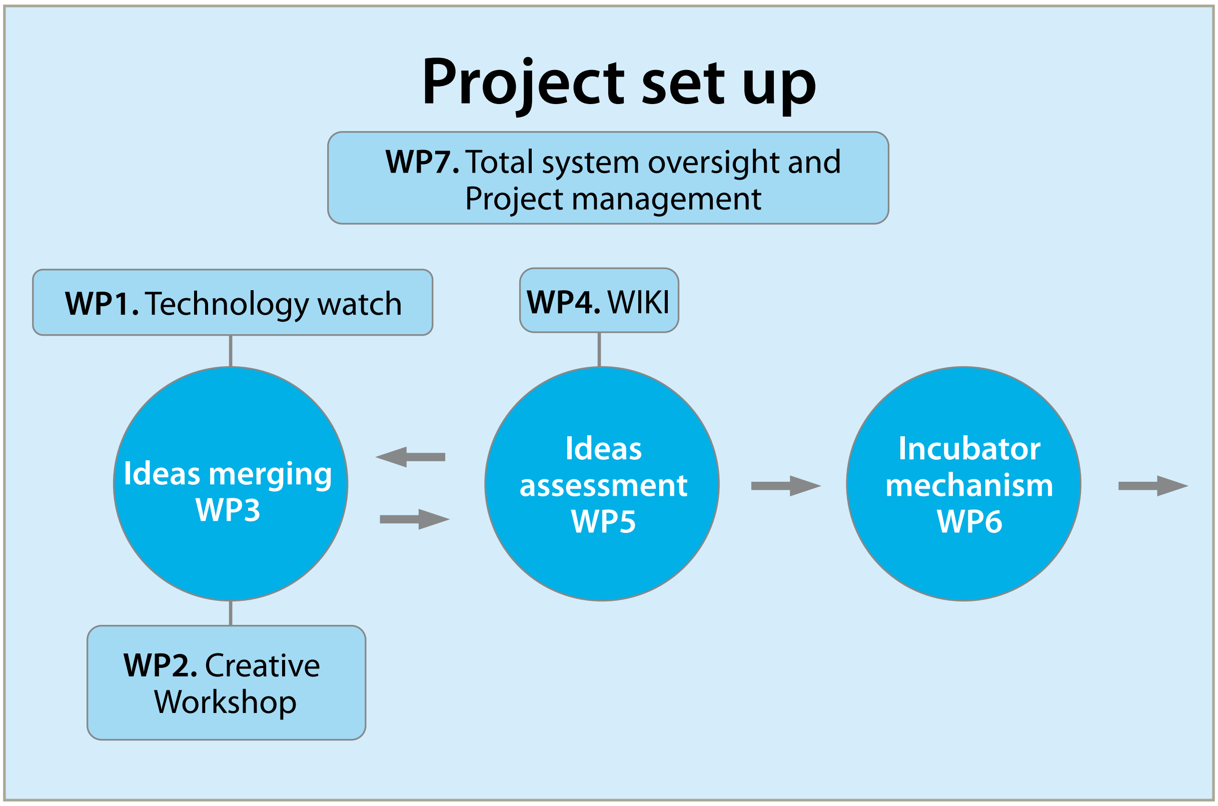
7.3.5 The proposed set of mechanisms will result in a structured process approach towards creative and innovative technology development in Europe. By implementing the proposed structure, Europe would have at its disposal a mechanism which, acknowledging all the differences, will represent for European aeronautics what DARPA represents in the US for military research and technology development.

> **'The proposed set of mechanisms will result in a structured process approach towards creative and innovative technology development in Europe.'**

7.3.6 Such a setup will require close cooperation between European stakeholders. These stakeholders are limited in number, are used to working together as in the Framework Programme and are joined together under ACARE. Therefore it is expected that such a setup would be successful as the networks are already well established.

7.3.7 The main elements of the proposed project will be:

- the European aeronautics technology watch;
- the creative workshop to generate new ideas;
- the merging of different ideas into consistent concepts;
- the access to ideas, resulting from the process and from other sources through the setting up of a WIKI type mechanism;
- the assessment of ideas in terms of feasibility, passenger acceptability, economic and technical content;
- the incubation of promising ideas.



Appendices

Appendix A:
The Assessment Team

Arnaud Lafitte
Chris Burton
Johanes Reichmuth
Luigi Bottasso
Marc Brochard
Marcello Amato
Jose Martin Hernandez
Matthias Meussen
Nick McDonald
Dimitris Mourtzis
Paul Kuentzmann
Phil Walsh
Jost Seifert
Patricia Pelfrene
Trevor Truman
Ad de Graaff

Appendix B:
The Original 100 Ideas

The majority of the ideas considered in this section are from the 100 ideas and concepts presented by delegates at the workshop on 10 and 11 October 2006. They are re-presented here, sometimes in combination with others, without critical review and explicitly without any judgement being implied as to their practical viability. The ideas have been grouped according to:

- **Systems of systems**
  The Airborne Metro
  Ground Power Augmentation
  Future Airport Systems
  Personal Transport Systems
  Future Airline Systems

- **System conceptual views**
  Reduced Aircraft Mass
  Next Generation Propulsion
  Modular: Morphing and Re-configurable Aircraft
  The Passenger Experience
  Globalised ATS
  New Aircraft Technologies
  Space

- **Subordinate concepts**

The systems of systems ideas

The ideas clustered together as "systems of systems" imply that substantial changes in these areas would profoundly influence the inter-connected system that is the ATS. It would be almost inconceivable for any one part of the ATS to adopt these ideas without reference to all the dependent and interlocking parts of the whole.

The airborne metro

This vast concept envisages an era when climate changing emissions, ground congestion and noise pollution will no longer be acceptable at their presently forecast levels. It seeks to sustain the apparently unlimited demands of people for travel without the huge penalties that these are beginning to impose.

The concept depends upon the feasibility of very large flight vehicles, carrying over 3 000 passengers and for these eventually to be nuclear powered. These large "Air Cruisers" would stay aloft on a semi-permanent basis receiving their loads of passengers, freight and supplies in mid-air.

Starting from the top level of the concept we could have the Airborne Metro system populated entirely by these long-range cruisers. They would travel on predictable, efficient looping paths that take each individual cruiser near to several major population hubs. Their flight paths would also be arranged to intersect with those of other cruisers so that links could be made to anywhere on the global cruiser network by changing from one cruiser to another.

Cruiser tracks would be followed by a considerable number of similar cruisers each following the other at intervals of perhaps an hour. They would be controlled from the ground and have defined track and altitude instructions together with emergency diversion paths. Reverse tracks would also be flown to provide more convenience for passenger routing.

> 'This vast concept envisages an era when climate changing emissions, ground congestion and noise pollution will no longer be acceptable at their presently forecast levels. It seeks to sustain the apparently unlimited demands of people for travel without the huge penalties that these are beginning to impose.'

At the level of the air-cruiser the system has many attributes of a metro system. It works to fixed routes, it has interchange locations and passengers can usually choose between several routes for the most popular journeys. Interchanges present specific challenges requiring two cruisers to fly with precision and to fly together whilst airborne for the exchange of passengers.

Feeding the cruisers with passengers and freight would require a fleet of locally based aircraft probably of a standard specification and carry 50-300 passengers. These aircraft would be equipped with docking facilities allowing them to link with the cruisers. The internal arrangements of the aircraft would also reflect this special-to-role design. For example, the loading might need to be streamlined to allow designated pods for transfer to the correct cruiser flight.

Airport congestion could be visibly reduced by such a concept. Airports would have a greatly reduced number of VLCT movements and would, instead, be focussed on the rapid throughput of passengers onto and from feeder airlines. This would allow the airport to be re-designed to permit, for example, four runway operations and visibly reduce airport holding populations. Passengers would have to take responsibility for part of this transaction and ensure that they boarded the correct feeder for their destination.

Booking "hard" tickets for a particular flight might be phased out in favour of a controlled board-when-you-come approach. Improvements in the power and reach of computer processes by the time of introduction would no doubt allow this to be adequately controlled with minimal passenger inconvenience and waiting. This would, to a large extent, compensate for the additional travel time resulting from the feeder/cruiser link. Passengers arriving at the airport would be able to register for a seat in the next available cruiser and thereby spend less time at the airport.

One of the greatest technological challenges would, of course, be the concept of docking. This would need to take place at relatively high speed - probably around M0.7 and would need to be fully and securely automated. For the feeder/cruiser link, and assuming that the cruiser was some kind of Blended Wing Body Aircraft (BWB), docking on top of the cruiser would seem practical. Research would be needed to ascertain the flow field around the cruiser and how these might be managed to allow docking. The docking mechanism and the flight characteristics of the docked pair would also need extensive research.

Ground power augmentation

This envisages using ground provided power through devices mounted on the airfield to assist take-off or landing. The benefits perceived for such use are that the aircraft might then be able to fly using less installed power and to use less energy taking off and landing than would otherwise have been the case. The benefits would be expressed in reduced carbon emissions and in lower costs.

An aircraft requires forward velocity to take off conventionally. This is generally obtained by accelerating the aircraft until the air velocity over the wing is sufficient for lift-off, possibly with the use of high lift devices such as flaps. One of the ways of providing ground power for part of this phase would be to hoist the aircraft to the top of a ramp and allow it to exchange the potential energy thus gained for kinetic energy as it rolls down the ramp. The benefits gained in this way do not appear to be sufficient for take-off as forward speeds of around 150 knots are required.

Incorporating a second accelerating device could, however, further enhance the elevated ramp. This would have some or all of the effect of a catapult in propelling the aircraft forward. Such devices could, for example, be maglev propulsion units in which the aircraft would engage with a trolley that was linked to the maglev track. The aircraft would be pulled back up the ramp engaged with the trolley and then both roll and propel down the track.

The maglev propulsive rail could, of course, be used with the ramp and the aircraft would then take off from a mainly flat surface.

Ski-jump take-off ramps have been used in naval vessels to provide a vertical impulse to shorten the take-off. These units have, however, been most notably used with very high power-to-weight aircraft like the Harrier that is able, on full power, to sustain flight even if sufficient forward velocity has not been achieved. The issue with a loaded airliner is that of achieving the necessary forward speed and a ski-jump is not thought likely to substantially assist such an aircraft.

A concept with a very different approach is the "Tube Take-Off" device (TTOD). This envisages a very large tube into which the aircraft taking off is reversed. In the tube behind the airliner is a large and powerful fan powered from ground resources. The airliner stands in the tube, engines running, whilst the fan runs up to speed and sucks air past the airliner until the air velocity over the wings induces sufficient lift for flight. The airliner is then able to exit the tube and to take flight. The challenges to be overcome with this concept concern the airflow into the mouth of the tube and the design of the tube itself. The aircraft needs to accelerate out of the tube so that when it reaches the free, stationary air somewhere outside the tube it has achieved an adequate flying speed. The airflow into the tube will be such that stationary air will not occur immediately at the mouth of the tube. The length of time for the aircraft to accelerate must be matched to the length of the tube from which it exits and the flow field distance outside the tube from which it may draw benefit. The flow field may be optimised by the design of the tube mouth.

Accelerating winches may also be used to assist the acceleration of the aircraft either alone or in combination with other devices. These winches would be larger versions of the devices used to launch gliders or the catapults used on naval aircraft carriers. The forces are very large. A typical medium aircraft has a maximum take-off weight of about 73 000 kg. Augmenting forces of around 13 500 kg would be needed to reduce the take-off length by 300 m. The main purpose of ground power augmentation (GPA), however, is to reduce installed aircraft power. In that scenario the same augmenting forces and the original take-off distance could reduce ground level thrust needed by up to a half which would be very significant for this phase of the mission taken in isolation. Thrust calculations can, however, be extremely complex. One of the calculations necessary is to determine the size of the engine that would sustain flight in the event of an engine failure. Clearly, it would be nonsense to suggest that catapulting an aircraft with no engines into the air at flying velocity would achieve anything useful. So, the installed power on the aircraft has to meet several other constraint conditions.

This situation is particularly dramatic on so-called big-twin aircraft where the calculation of engine failure on take-off is often the critical determinant of thrust. Airworthiness regulations require that these aircraft be able to gain height on or after take-off even with failure of one engine . This has lead to most of these aircraft having considerable excess thrust installed, to an extent approaching twice the thrust calculated to be necessary without the engine failing. Four- or six-engine configurations have a lower requirement for such excess thrust since the take-off safety requirement concerns the failure of one engine. The four-engine configuration thus leads to each engine needing something less than 1.3 x the calculated figure. In practice, the observed amount of "excess power" at take-off in a large four-engine aircraft is about 25 %, equivalent to one of the engines.

One approach that has been proposed for overcoming this emergency requirement has been to install thrust-augmenting devices. These could, for example, be modern developments of the old JATO units that provide an emergency source of thrust or are routinely used for take-off assistance. In the GPA concept the installed thrust of an aircraft might well be determined by the single engine failure mode rather than the take-off thrust requirement. With two JATO-like devices capable of providing (on our reference medium weight airliner) an emergency thrust of perhaps 2 x 3000 kg this consideration might allow a more closely balanced determination of installed engine thrust.

The landing concept is that aircraft weight can be reduced if the landing site can apply ground power to assist the aircraft in its approach. Delivering benefits from such a concept is challenging. If the power to be supplied is some kind of force field, perhaps from very large electro-magnetic poles, the field would be very directional but would become very weak in the free air space. The power of magnetic attraction between two magnets is reduced at high inter-pole distances according to a very high power of the separation. Only very weak field strengths are therefore possible at sensible aircraft separations even with very powerful magnets in both the base and aircraft.

Future airport systems

Airports are an essential element in the ATS. Airports began as aerodromes, where the boarding of passengers was the essential function. Since then, airports have diversified into hubs and regional airports where there is a strong desire to be more than an aerodrome and many airports have become a combination of air station, shopping mall, business centre and parking lot.

> **'It is time to take a fresh look at airport operations and to develop new ways to handle passengers and goods at these nodal points.'**

Unless the ATS will become completely structured around vertical take-off and landing (VTOL) aircraft, airport functions are here to stay. Airports are related to four major elements in the ATS system of systems: the passenger; the ATS security; the ATS capacity and the surroundings of airports. There is

also a strong link to multi-modal transport chains. If air transport is to grow, sufficient airport capacity will be needed. At this time, the 43 European hub airports that still handle 85 % of the European traffic are congested and some are reaching the limits of their capacity. There are some 2 200 other airports in Europe (including 450 main regional airports) that are currently under-utilised. But these airports are often not located near the main populated areas of Europe where traffic flows are most dense.

The development of the airside of airports has not changed much since air transport began. The way passengers, cargo and planes are handled is basically the same as 50 years ago (although many processes have been automated).The additional security measures that are now required have complicated the procedures at airports. Many passengers will experience time consuming and sometimes humiliating security checks, which are not designed to handle large numbers of passengers all at the same time. Different organisations have to work together at an airport, which can easily create disruptions to the handling of passengers and goods.

It is time, therefore, to take a fresh look at airport operations and to develop new ways to handle passengers and goods at these nodal points. We must keep in mind the ACARE target that a passenger should not be obliged to spend than 15 to 30 minutes from time of arrival at the airport to boarding a plane. The concepts address three basic elements of the airports:

- handling of passengers
- capacity increase
- reducing the environmental impact
- the passenger

Check-in at airports can be a time consuming affair. Remote booking and check-in will reduce the time lost during activities that the traveller will regard as non-essential. A possible solution will be to enable check-in at the aircraft gate.

Currently at airports there is little distinction made between passengers that are willing or unwilling to spend time at the airport, and so shopping and other activities are offered. Some people, mainly business travellers, want to spend as little time as possible at the airport. If shopping is required, this could be done onboard the aircraft and the electronic orders would be available when the passenger returns to their home or away destination. This procedure saves time and the passengers are not required to carry extra luggage onto the aeroplane. (Such a system is already available at some airports or some airlines).

Most airports do not have facilities to separate the flows of leisure and business travellers. Both groups have to be submitted to lengthy security procedures. Passengers could be offered the possibility of using modern ID technologies for guidance and tracking through the terminal, and to be chipped. The chip would be implemented in the passenger's body. Security checks could be reduced by remote reading of the chip data, video recognition to check that the chipped person is the one he/she claims to be and an electronic body check. This could all be integrated into a simple full-body scan corridor which passengers are requested to walk through.

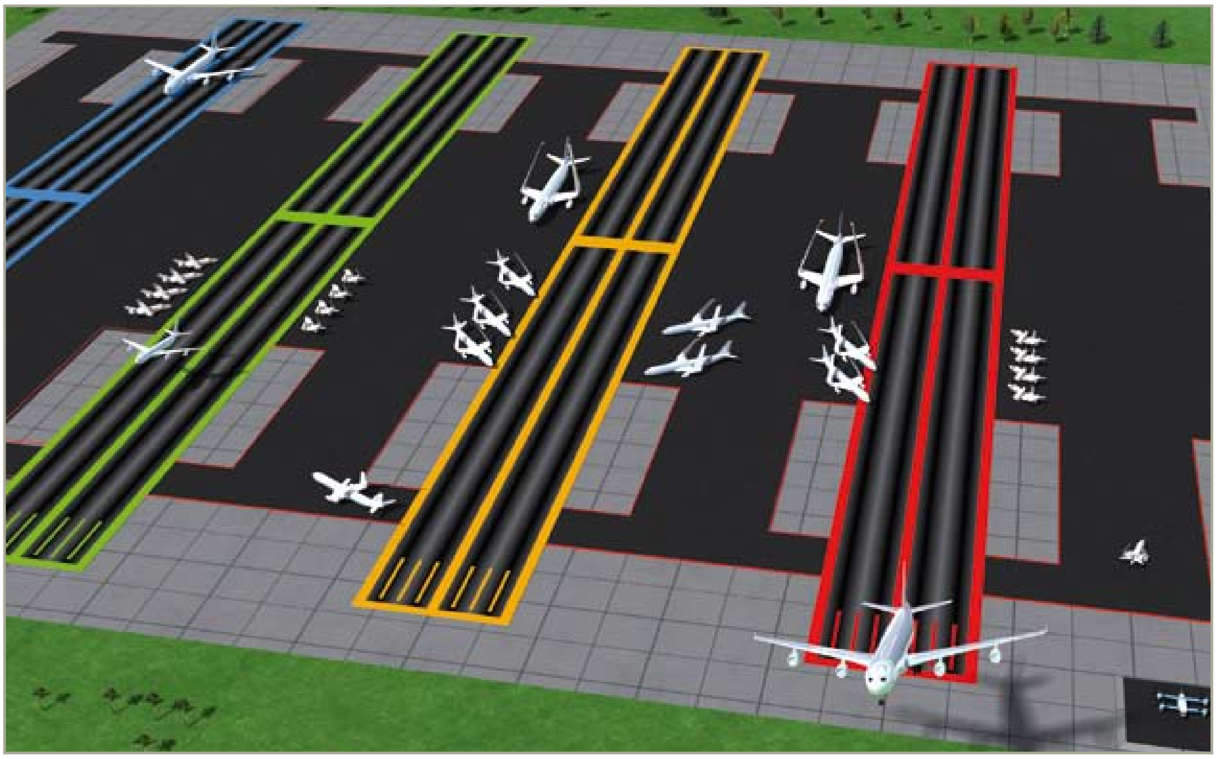
If no hand luggage is carried, as is proposed in another chapter, the process could be speeded up even more significantly. Such a set-up would take into account that more than 90 % of passengers present no threat to the ATS.

The layout of airports follows a traditional set-up that has been in use since the beginning of aviation. Passengers and goods are collected at terminal buildings; runways are connected to these terminals via (often long) taxi-ways; passengers are transferred to the aircraft via gates at the terminal building. At some airports passengers are transferred to the planes on the apron by busses departing from the central terminal. Luggage is taken to and from the aeroplane via a centralised luggage handling location. The current set-up requires the use of a substantial amount of land for taxiways.

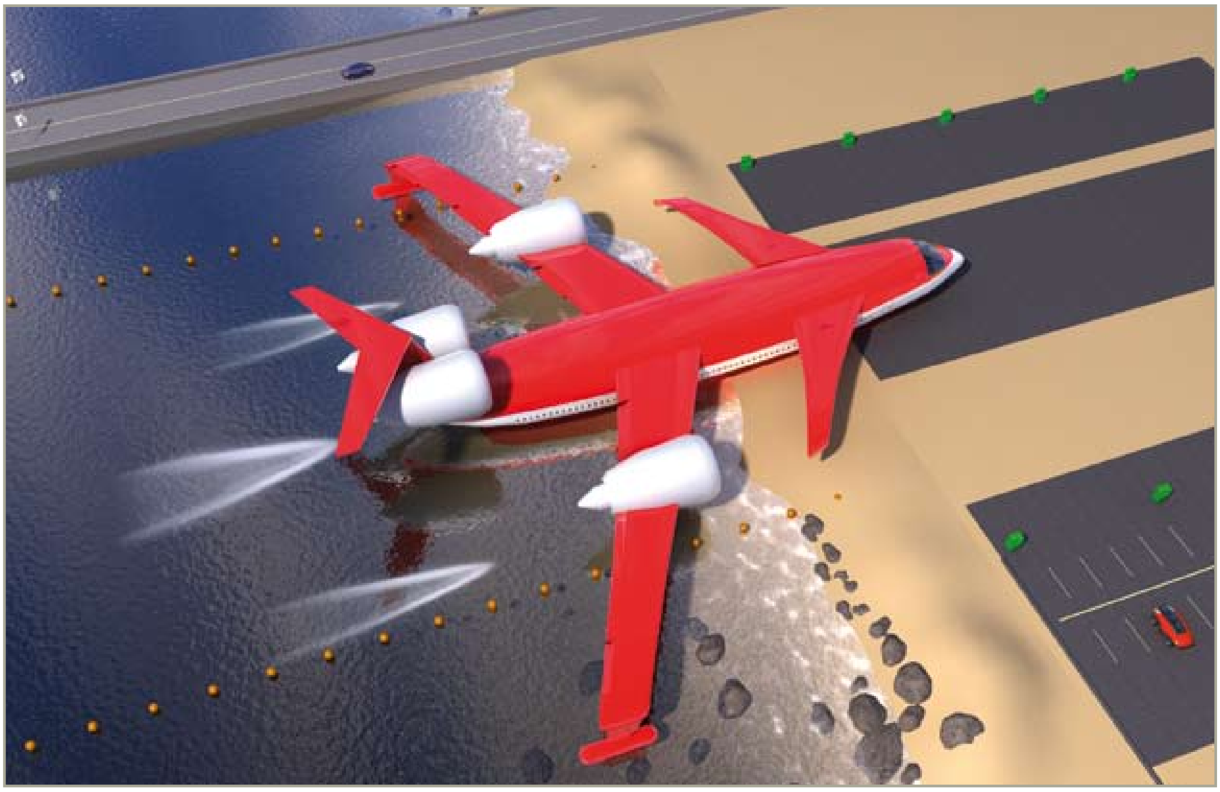
An alternative would be to locate the landside activities at the airport as much as possible near the runway and preferably under the ground. This concept follows the rule that the aircraft will not come to the passenger but the passenger will come to the aircraft. Passenger transfers will be done via fast people movers under ground. Passengers will stay with their luggage as long as possible.

One concept could be to co-locate access to the aircraft with the access to other transport modes. This would create the drive-in terminal where check-in will be at the aircraft gate.

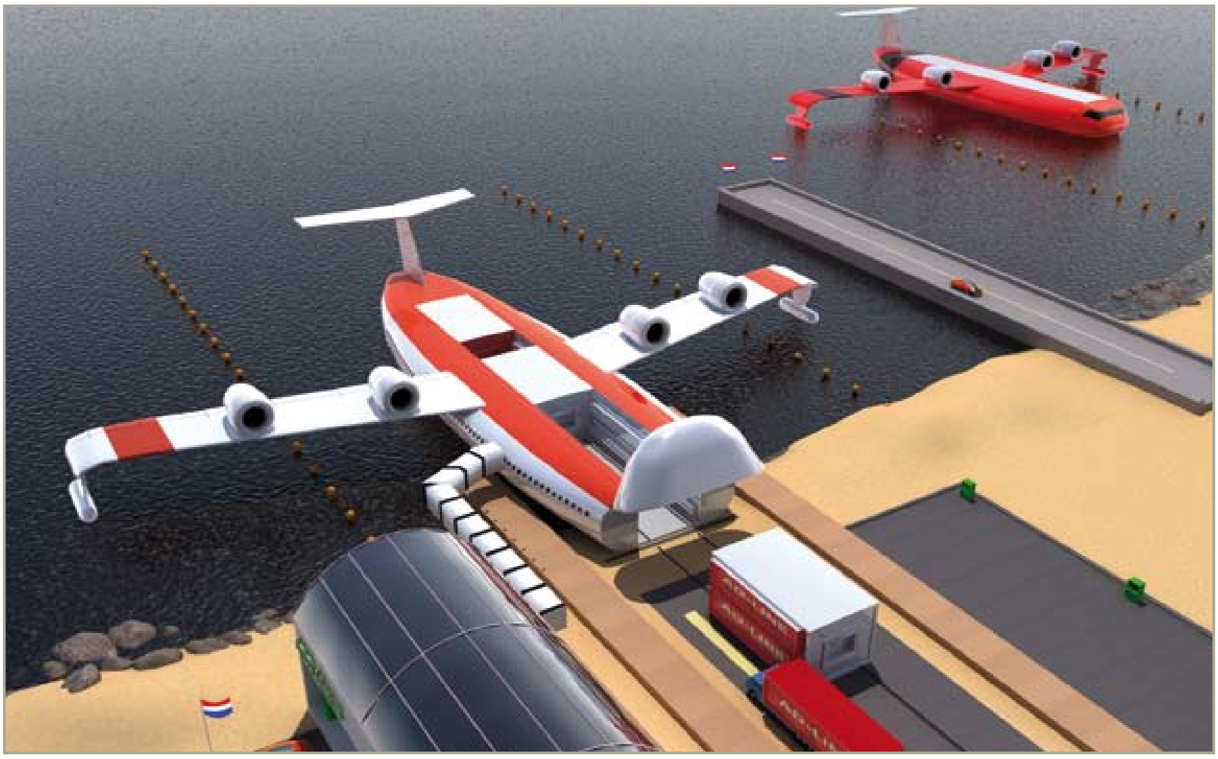
With such a concept, additional runways could be created within the perimeter of the airport. This is important as airports are centres of economic activity and normally attract business parks which are situated as close as possible. This often makes expansion of an airport a difficult task with no additional land available. Airports serve as multi-modal nodal transfer points. In another part of this report the idea of multi-modal containers that will transport people and their luggage is explained. These containers would speed up the boarding of aircraft even more, as these would be inserted in the aircraft directly.



A different concept is an aircraft service street along the runway, where aircraft are being readied for the next flight while passing a number of service stations and gradually roll towards the runway threshold. If insufficient airport capacity exists in certain parts of Europe, an alternative could be to locate airports on European shores.



It is a well known fact that most densely populated areas are normally located at the shores or are well connected to these. Such a set-up would require the development of new amphibious aircraft. An alternative could be the development of dedicated cargo ports at the European shores to free some airport capacity at European airports and satisfy the ever increasing demand for air cargo capacity.

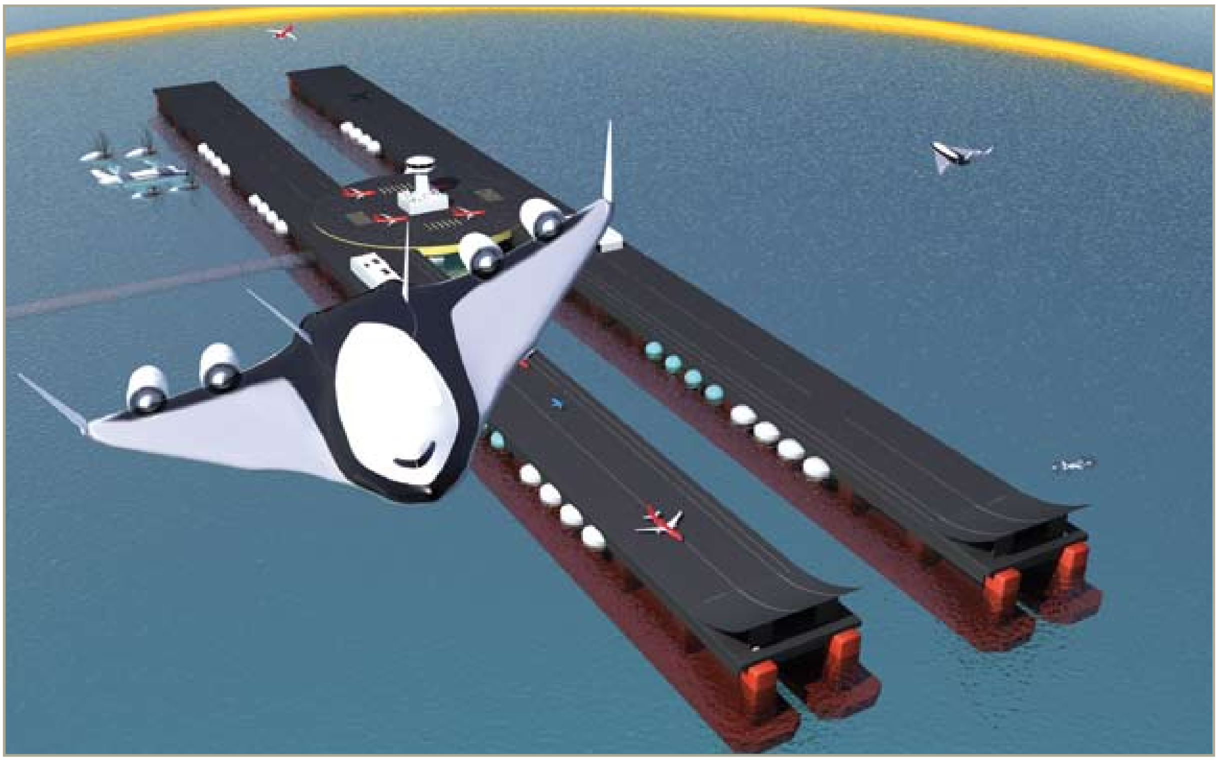


A totally different approach would be to locate airports high above the ground in densely populated areas. These could be heliports that could accommodate (feeder) VTOL aeroplanes. One could even imagine an airport situated above the ground. Such an airport would be able to accept large aircraft as well. Such a structure would be rather big and although it would reduce noise and pollution near the ground, it would have other major impacts on the environment and for those living next to it.

An alternative could be an airborne air station, that could be placed in between the Metro liner previously described and small air vehicles that would provide a personalised service to the passenger. These airborne air stations would be located several thousand feet in the air so that they would have a limited impact on the environment at ground level. As these stations would be in principle stationary or local units, use could be made of the flywheel principle to power these stations. Power could be provided by solar and nuclear energy sources or by beamed energy.

> **'In some situations, an airport at sea could be considered. One can imagine the construction of airports at sea as an overflow facility of large existing hub airports.'**

In some situations, an airport at sea could be considered. One can imagine the construction of airports at sea as an overflow facility of large existing hub airports. The alternative could be to relocate major airports out at sea. There are already some examples in Japan and in China where major airports have been relocated in littoral waters. If traffic growth continues as predicted, one might even think of very large aircraft transporting people and freight on intercontinental routes and stationed at international super-hub airports located in international waters.



Seaside airport structures have been built in littoral waters. If new airports are to be located on the high seas, floating airports could be constructed using the semi-submersible technology applied in the off shore industry. Since these are floating structures, they could be turned into the wind to maximise capacity. There could be a floating dyke around the structures to minimise the effect of high sea states. The advantage of a floating airport over an island structure could be that the marine life is less affected by the airport structure. Also, it could be a more cost-effective solution than building an island in deep waters. These floating structures could be of modular design and be extended as traffic flows increase. The floating airport could be directly linked to offshore wind turbines and offshore hydrogen fuel production sites.

Personal transport systems

Every science fiction writer of the 1950s seemed to incorporate some kind of personal flying machine. People of ordinary means could load up, take off and travel in uncrowded skies to visit relatives. Today we have the same ambitions but a greater realism about the challenges that will present themselves. We are, however, also armed with infinitely greater technologies and so the time to re-examine such personal transportation systems (PTS) is appropriate. Today's concepts are more varied and more practical than Waldo Waterman's "Whatsit" of 1935 with its detachable wings and car-like fuselage.

There is a wealth of literature about both historical and current attempts to crack this attractive nut. Agencies such as NASA and Boeing as well as individuals in sheds at home are equally taken with the concept. Some 70 concepts are being worked on today, some have reached flight trials and some remain, probably firmly, locked into the concept stage. None have yet been effectively marketed or sold on the world market although some, like the Wallis Autogyro come tolerably close to the concept. The design of PTS vehicles is extraordinarily varied with concepts for jet-packs, personal flying machines, aero-cars and others.

The more serious teams recognise that designing the air vehicle is only a relatively small part of overcoming the challenges. It seems likely that this small part will be solved in this century. The other challenges remain, although they too are receiving attention. The issue of control by an unskilled pilot, the doubtful quality of runways that will be used, the major issue of safety and congestion, the question of policing, of licensing and regulation, the resilience to bad weather and the pilot's ability to take this into account are all issues that now hold the attention of the serious PTS builder.

Most builders follow the strict line of the PTS, a personal aircraft. Other ideas involve the creation of individual lifting devices that, when coupled together or separately attached to a load, could raise heavier objects. Some single central controller is foreseen to manage the units and to direct the flight.

‘Under present expectations air traffic is set to increase by as much as 4-5 % per year for passengers and up to 6 % per year for freight. Over two or three decades this would equate to massive additional demands on every aspect of air travel. It is possible that some of the most cherished conventions of the airline industry will be under pressure and require new business models if the challenges of the late 21st Century are to be met.’

Future airline systems

The concept of an airline has remained almost unchanged since the dawn of air travel. A state or business buys and operates aircraft, charges passengers and freight to travel on them, and so calls itself an airline. They operate from airports that are usually owned by someone else and pay fees for their use. In recent years, this simple model has changed somewhat. As airport congestion has increased, the notion of the airline owning take-off slots has become more dominant. The trend toward out-sourcing catering supplies has led to the formation of great enterprises specialising in this line of work on behalf of many airlines. In recent years the pressure on the major hub airports and the increasing amount of time that passengers are asked to spend there, has once again raised the idea of point-to-point journeys. The latest major change to the air travel industry has been the advent of the low-cost carriers (LCC) which has accounted for a large percentage of recent increases in air travel.

Under present expectations air traffic is set to increase by as much as 4-5 % per year for passengers and up to 6 % per year for freight. Over two or three decades this would equate to massive additional demands on every aspect of air travel. It is possible that some of the most cherished conventions of the airline industry will be under pressure and require new business models if the challenges of the late 21st Century are to be met. Several ideas were put forward that are relevant to this situation.

The airline airport

This concept envisages that an airport could become sufficiently dominant in an area for it to embrace the role of flight services (the airline role) and operate as a "through service" provider from passenger arrival to destination. This would allow the operator many new ways of being flexible that could flow through to improvements in passenger value. Its hold over the slot regime at the airport, ownership of the retail outlets, ownership of car parking and transport interchanges combine to allow it to offer to the consumer prices for each individual part of the operation. Passengers would also have a single accountable operator one who would be answerable for any shortcomings regarding every aspect of the passenger experience. This would avoid the sensation of being passed from airport to airline to service provider to baggage handler when pursuing a satisfactory outcome to a problem. Although this approach may bring substantial benefits to some passengers, others might fare less well. If, for example, car-parking fees were used to subsidise airline costs those travelling short distances but parking for long periods would be at a disadvantage. This is a common feature of any broad-spectrum business and it would be balanced, just as in any other business, by optimising the overall outcome for the company. If the airline-airport became very large in one geographical location, there might be a perception of reduced competition and the opportunity to implement unreasonably high prices.

Other airlines wishing to fly from the "airline-airport" would like to be assured that they can do so economically and not be subject to unsavoury business practice from the main operator. However, it might be in the main operator's interest to attract several other airlines flying non-competing routes if this could increase financial benefits. In such a case, the terms negotiated would need to be acceptable to both parties.

Airline business models

The previous concept begs the wider question of what business model should be applied to air travel. We are all familiar with the traditional concepts in which the airline owns the resources and maintains them; the airline also pays the airport to use its real estate and the passengers pay the airline. This model has already been substantially changed by the LCCs. Some already work on the basis that the airport pays the airline and makes its money from retail parks in the airport. Travel companies are charged very little by airlines because they take a broader view of income in charging for holidays. Airlines often do not maintain their own aircraft but sub-contract maintenance to others. Engine suppliers often do not sell engines to airlines but instead sell them engine availability. Therefore, the number of business models available rapidly increases.

This opens up the whole chapter of how aviation is to be financed and what the implications of different models will be. It is perfectly possible to imagine that companies could join together and offer "free" flights on the basis that there will be associated ways of relieving passengers of their money through retail purchases, holidays, hotels, car hire and much besides. The lure of nearly free flights is already with us with the LCCs. Much of the rise in aviation traffic is due to their success. This is now attracting critical review and allegations that the climate warming effects of LCCs are not worth such low-priced tickets. This has now been extended to demands for fuel to be taxed as a means of ensuring a rise in the price of flights.

Some argue that fuel taxes are regressive. Others state that a European fuel tax will actually increase global warming because it will encourage the airlines to save fuel taxes in the most obvious way, i.e. by buying fuel from outside the taxed zone (Europe assumed) and transport it further resulting in higher costs and increased pollution. Others point out the need for a massive increase in new research to create technologies that will address these serious problems and that fuel taxes are unlikely to find their way to funding these programmes.

Emissions' trading is the most direct way of influencing which business model will bring least damage to the global climate. However, to have the claimed effects, the emissions trades would need to be between the individual (who is the consumer) and the provider of the services. Unless individual consumers use up their personal carbon allowance and make choices between, say, a car journey, a flight, or a patio heater they will have only marginal effect. More seriously still, the application of regional arrangements for personal carbon trading is unlikely to have beneficial effects whilst people outside their area are exempt from such constraints.

Within this uncertain, intractable, variable situation, the development of new business models for aviation will struggle to find the best route. Some experiments will succeed by chance while others fail. What is already clear is that the development of aviation business is entwined with public interest in the consequences. Suggesting options that may be possible for the former without considering the effects on the latter are unlikely to prove satisfactory.

Revisiting slot allocations

Since the original aircraft owners started selling tickets to passengers, the concept of the airlines' ownership of the "slot" has been inherent to the relationship between airport and airline. For many years, its significance was not highlighted and it simply formed a convenient means of regulating airport usage. As busy hub airports have become more congested, the slot has become much more important. Many airlines want the same slots at peak times and the resource they fight over i.e. runway access is limited. Worse still, major carriers have been granted "grandfather rights" that ensure their continued ownership of valuable slots either by themselves or through their alliance partnerships. The use, sale and management of slots have now become a major driver in airline economics.

Within the European Community, the Directorate-General for Energy and Transport has been taking soundings on a new approach to slot management. Their concept is for slots to be opened up to a secondary market allowing the airlines to buy and sell slots. The Commission's view is that this market will go some way towards the desirable customer outcome of the most valuable slots belonging to the most efficient airlines. There is substantial support for the concept and it is agreed that it will move the system towards a freer market and to a reassessment of slot allocation. However, problems will still remain if this idea is implemented. It is far from certain that inefficient airlines will be prompted to sell their most valuable slots and may instead opt to continue using them because of their importance within both their own and their partnership route network. Readjustment of the market is not expected to be other than very slow and imperfect.

The discussion about slots has been confused by the history of major airlines, many of which are national flag carriers and, in a number of cases, are state owned. This gives rise to perceptions of state pressure in support of the national airline, to anti-competitive stances and to a number of policies that inhibit free and open competition. Another obstacle to change is the Chicago Convention that prevents any airline from collecting passengers anywhere other than in its state of registration without permission to do so. This also gives states powers to regulate airline structures and lays them open to pressure from their national airlines.

A more radical approach would be to return to the basic truth of the scarce resource – that it is a property of the airport and not the airline. Were we to take this view it might be possible to gradually return all slots to airport ownership and then to lease them to airlines. Such a major adjustment could not, of course, be introduced suddenly without chaotic implications for the industry. Nevertheless, within a programme it might be possible to give notice of intent that all slot ownership rights would be terminated some years on to all operators. Thereafter, slots would be leased for operating periods of some years with lessees able to buy and sell residual lease periods.

The systems ideas

Reduced aircraft mass

The pressure upon fuel reduction that will lead to reductions in the climate warming effects of hydro-carbon fuel burn will probably increase. The amount of fuel burnt depends on the weight, speed and drag of the aircraft. One of the ways to minimise fuel burn lies in substantially reducing the weight of the aircraft. Weight is made up of structural weight, fuel weight and systems weight.

Reduced Structural and Payload Weight

Some of the ideas dealt with in other sections may have relevance here: the use of ground power augmentation may serve to reduce engine thrust or the use of detachable or ground located undercarriages. However, the most effective approach to a better relationship between power, weight and payload seems to rest with new concepts for the design of aircraft. The concept that appears to receive most support is the Blended Wing Body. The savings of drag achieved by its tail-less nature are significant and the Lift/Drag function in designs being studied is about 15 % higher than current design conventions.

'The concept that appears to receive most support is that of the Blended Wing Body. Savings on drag achieved by its tail-less nature are significant and the Lift/Drag function in designs being studied is about 15% higher than current design conventions.'

Reducing the structural weight of a given concept will bring about benefits dependent upon its operational use. Broadly based figures suggest that the percentage taken off the weight of the aircraft, engines and systems will produce a 1 – 1.5 times greater percentage saving in fuel burn per tonne-kilometre.

It may be possible to reduce the carried weight of the cabin crew by installing server systems that dispense food, drink and incidental items to passengers in flight. Concepts of zero-baggage or self loading baggage might also serve to reduce the baggage weight carried. It is not known at present how significant the net savings would be.

Reduced fuel weight

On long-haul flights in particular, the carriage of the fuel carried by the aircraft itself incurs a considerable cost in fuel used. A number of methods have been suggested to optimise the balance between fuel carried over long stages and the additional fuel used for landing more often. In the UK's Greener by Design paper , this optimisation is dealt with more extensively and the conclusion drawn is that for many aircraft an optimum stage length is about 4 000 km, allowing savings on long-haul flights of 10-20 %.

Air refuelling

This is commonplace for military aircraft and the technology is well developed. The benefits would arise from reducing the fuel carried for the latter parts of a journey – this fuel could be loaded much nearer to the destination and allow smaller aircraft with smaller fuel loads to operate. Such a technology could be extended to commercial operations. Significant savings on fuel burn can be expected by employing this method. However, more study is required to identify practical and achievable net benefits when fuel expenditure by the tanker fleet is taken into account . Flight re-fuelling of airliners might become routine, saving some of the fuel used to lift massive fuel loads from the ground and carry them halfway around the world.

Formation flying

Every naturalist is familiar with the sight of skeins of ducks flying into the sunset in their typical "V" formation. The intention is to employ both of these ideas in the air transport system, the result being significant savings in fuel consumption, fuel carriage and an improvement in air traffic control (ATC).

Tight formation flying involves avoiding on a regular, reliable and secure basis any adverse effects from the weight dependent vortices from the wings of the lead aircraft. Vortices are a function of aircraft weight and commercial airliners are substantially heavier than all other aircraft that have attempted close formation flying. Conceptually, the benefits are considerable. If the reduced drag that ducks create by wing warping to reduce their individual effort in flying long distances can be harnessed, then long range travel could be substantially more economical. Research already conducted shows that cruise fuel savings could be 15-40 %. Wings flying within about 0.8 m of each other can experience a 60 % reduction in drag. Practically achievable fuel savings (and fuel carriage) in the order of 10 % have been estimated. Groups of aircraft (such as on the busy intercontinental routes) could be treated as a single entity by ATC as they sometimes are now. In the future, groups of similarly routed aircraft could form "fixed" formations in which the aircraft become a single flying system under a single control which only disperses as aircraft wish to drop off nearer to a destination. The technical resolution of the problem of reliable and secure close flight would be very relevant to other concepts (such as the Cruiser/Feeder last page).

Reducing systems weight

The concept of launched aircraft with some form of airport retained take-off undercarriage was discussed. Were such an idea to be feasible, it would bring substantial benefits by eliminating one of the heaviest systems on the aircraft. On initial consideration, it is relatively easy to imagine how the take-off might be accomplished with the undercarriage being left behind. Landing would be much more demanding. Firstly, the loads upon landing are much heavier so the prospect of any lighter weight "landing only" undercarriage is immediately to be rejected. Landing at normal speeds would have catastrophic consequences. At present, the only idea presented that appears feasible is landing within a landing tube where the "touch-down" speed is extremely low or effectively zero.

Parafoils are used to deliver military supplies. The advantage over a traditional parachute is that these parafoils can be steered. The current loads that can be used with these systems are relatively small. If the technology could be developed to allow aircraft to make parafoil-assisted landings, noise produced by aeroplanes during descent and landing could be substantially reduced. One could imagine an airport where aircraft are launched by MAGLEV systems whilst runways are only used to recover aircraft using parafoil-assisted landings. As the final landing speeds would be extremely low, a simple skid undercarriage would be needed, saving at least 5 % of the total aircraft weight. Landing strips could be much shorter than the current runways.

The parafoil technology would need to be further developed. First, one needs to consider the additional weight that would be carried. Second, the parafoil glider should be able to operate in cross wind conditions. Third, the accuracy of the system should be extremely high with an accuracy of about one metre.

Another issue that needs further research would be the mechanism to open and retrieve the parafoil. This should be done totally automatically. Steering the parafoil should be automatic with manual override possible if needed.

Next generation propulsion

The majority of travellers have at one time or another travelled in aircraft equipped with a turbo-jet gas turbine engine. It is a design concept that is reproduced by all the major manufacturers and is made in substantial quantities. High by-pass ratio all jet engines power the great majority of the 11 000 or so large commercial aircraft that fly today. In their latest form, such engines can each deliver thrust well above 120 000 lbs which would have been met with astonishment only three or four decades ago. The question posed by this series of ideas is whether the convergence upon this single formula for design bears any relationship to the form of aircraft engine required in the future. The question arises as to whether this form, suitable for its era, is entering a new era when another form of propulsion engine will take over the position the turbo-fan has today.

The question is prompted by increasing pressure as a result of climate change. The media seems to be focussed on the story that aviation will become the Number 1 polluting mechanism later this century. This is most unlikely to be the case and will certainly not be true if it is managed correctly. Aircraft emissions do have an effect, although we are not yet sure exactly what this effect is, or precisely how the mechanisms involved work. It may be that aircraft emissions have a relatively greater effect upon the sunlight coming through the atmosphere than ground level emissions do. The question remains unanswered.

Nuclear engines

Despite the obvious risks and difficulties, nuclear engines have obvious attractions. They make no airborne emissions and their waste can be safely and securely handled on the ground. The technical engine problems are well on the way to being solved. The concerns for safety and security may be overcome, but almost as difficult will be the perceptions of society for airborne nuclear engines and their containment. So, any programme of technical research needs to be accompanied by social research into the acceptability of these engines.

Of course, many technical problems still remain, but the nuclear engine offers a path from heat to propulsion that utilises many of the same heat exchange technologies that we have already developed. Many of these might make the nuclear engine very similar to a jet engine without the fuel pumping and combustion mechanisms. A number of suitable prototypes for nuclear engines have been built at various powers. Reactor volume and weight as well as containment have always been the intractable issue. Either the weight of the containment becomes excessive for an air vehicle, or the containment is selectively reduced and the vehicle becomes a hazard for those outside it. These considerations brought to a halt the last known significant attempts to produce a nuclear powered aircraft. Perhaps with new containment materials and a growth in the size of the intended air vehicle, the equations for the containment can be revisited.

The issue of accidents is another major issue, both in reality and perception. The public perception is that nuclear engines are little better than flying bombs and are able to devastate vast areas if they were to crash. There is no reason to take this view but the public has been exposed to similar stories for so long that the issue will certainly re-surface. The reality is that careful measures would need to be taken to ensure that the nuclear material was prevented from contaminating surrounding areas in any conceivable accident. This not only includes the reactor chamber but also the pipes, valves and routing of any of the nuclear pathways in the whole unit.

Plasma technology

These electrical effects could be conceived as having two applications; either for direct use in propulsive force by having wing and fuselage surfaces made with the correctly embedded electrodes, or by drag reducing measures influencing air flow over the airfoils.

The science of para-electrics is becoming better understood and practical experiments have demonstrated their effects. The task of employing large-scale structures with adequately robust controls remains to be completed. So too are the power and weight reconciliations that would be realistic against the weight and power budgets. It has been asserted, for example, that the plasma effects equate to little more than pushing energy ahead of the aircraft. It makes the medium easier to fly through, but with the power needed to make this effect interchangeable with the power needed to propel the craft without the plasma effect. It is known that a blunt body can be made faster by forward facing (i.e. reversed) jet engines that work on a similar effect. But these examples do not explain the complexity of plasma science. Work continues in subsonic, supersonic and hypersonic regimes and there is much that remains to be discovered about the benefits and limitations of plasmas. Other effects besides propulsion may prove to be important, including the effect of the plasma on the radar reflection of the craft.

The weight budget required for high power plasma physics on-board is also challenging scientists. The plasma generating equipment will demand its own part of the weight budget and it is not known whether the overall systems outcome would be positive or negative.

Fuel cells

The fuel cell has captured the imagination and efforts of many engineers around the world. Its ability to take two common gases, hydrogen and oxygen and to create energy and water offers a clean, climatically sensitive way to generate energy. Small fuel cells are being produced and marketed already and are well beyond the laboratory stage.

Today's technology only contemplates an auxiliary power unit to augment but not to replace the main power plant of the aircraft. To manufacture large, propulsion level fuel cells will require advances in the energy density of the stack. The Georgia Institute of Technology has experimented with a UAV propelled by an advanced proton exchange membrane but it generates only 500 watts.

One of the fundamental issues concerning a large fuel cell of this design is the storage of the compressed hydrogen. The pressure vessels for a liquid gas system are large and heavy and represent a major obstacle to deriving practical designs for significant ranges in full size vehicles.

Another approach is the hybrid fuel cell running on energy dense carbon fuels. The Solid Oxide Fuel Cell (SOFC) hybrid being studied by NASA uses liquid methanol as the fuel. This combined system of directly reforming fuel with a gas turbine end stage offers the best balance of weight and power to date.

Solar cells

Solar energy has been proposed as an idea for the future of aircraft propulsion, or as an augmentation to it. The idea is attractive since the sun's energy is free and at higher altitudes it is easily available. The challenges are also great: the sun does not shine throughout the day and some kind of interface between the sun and the engine is usually necessary; most commonly a battery is used. The weight of the battery used for this purpose on one long range experimental aircraft weighed nearly half of the aircraft's weight. Whilst the battery fraction may not always need to be as high as on this aircraft, which was intended for sustained night flights, they still represent a formidable obstacle to the use of solar power.

The power generation of the solar cells is also a problem area. The present efficiency of power conversion to power incident is at a low level, somewhere around 20 % with a theoretical maximum believed to be of about 30-plus percent. The area needed to produce 1 Kw of output power is presently about 5 m^2. For a medium 150 seat airliner the wing area is around 122 m^2. The level of solar power produced if the wings were fully covered, would be in the order of 25 Kw. This compares to a typical fan-jet engine rated at around 10 000 Kw. While the figures may not be precise, they clearly illustrate the gulf between solar power and today's jet engines.

Most solar cell power has been applied to auxiliary power units and to very low-drag experimental aircraft designed on a glider-like principle and able to maintain altitude with very small injections of power.

Distributed propulsion

The concept of distributing propulsive force over the aircraft instead of having two or four discrete engines has interested engineers in several ways. The idea presented in the workshop was that by having multiple engines, right down to covering the surface with tiny engines, these may be integrated better and more flexibly with the mission. The benefits sought were to reduce the overall fuel burn whilst giving better control.

Several design schemes have already gone some way towards fulfilling this idea. One scheme from NASA Langley for a BWB has a modest number of core engines embedded in the wing, exhausting across a wider span than usual. This design shows predicted savings on take-off gross weight (TOGW) of about 5 %.

Incorporating blown flaps into the design of distributed thrust also brings benefits and new concepts, joining together these ideas shows considerable promise. Moving from a modest number of engines to many engines represents further complication and it is not yet clear how this would be accomplished in terms of the mechanical design. The particular benefit of having a mass of very small engines contributing to thrust is not entirely clear. The main purpose of any engine is to provide thrust alone, lift alone or some combination of the two. For a thrust alone set of many engines, each has to be aligned and arranged to contribute to the thrust vector – either directly or via inter-connected ducts. For lift alone, the placement of the engines would need to allow the lift component to be achieved, again either directly or via ducts. Engines with a combined role would have some additional complexity in allowing the force of the engine to be directed to one or other use in a controlled manner. For many small engines a ducted system would probably present considerable friction losses to the propulsion system.

Modular, morphing and reconfigurable aircraft

Each of these themes has the common idea that the aircraft need not be confined to a single design standard for its entire life. Modular aircraft design seeks to achieve this by connecting different modules together in a flexible and changeable way. Morphing aircraft achieve similar changes to configuration by reversible changes to the structural units in-situ. Re-configurable aircraft are effectively a sub-set of modular aircraft and have changes made by exercising one of a pre-planned series of possible changes to give a limited number of variants to the original design.

The potential mechanisms for achieving these changes are numerous. Modular aircraft (and their re-configurable sub-set) can be based on changes to equipment loaded into pre-prepared bays in the aircraft. These may be of importance to the aircraft mission systems but have relatively

little effect on the aircraft flight characteristics. More fundamental changes to the aircraft have been envisaged. These include pods that may be attached to provide different uses for the aircraft, power-plant change routines, individual passenger enclosures or personal seat units, and wing sets for different duties.

Each of these modular changes seeks to achieve a similar end i.e. to provide the aircraft with greater flexibility of use, to reduce its use in sub-optimum configurations, to increase its service deployment time or to reduce its loading and unloading times. The degree to which they achieve these ends depends upon several factors:

- Is the aircraft type going to be used (mainly) in a single role?
- Is the "modularity overhead" (the excess of weight to achieve the modular changes) going to outweigh the advantages?
- Is the safety of the aircraft compromised?
- Is the cost going to be excessive?

Where the answer to these questions is negative, the feature, at least potentially, will be successful.

Modularity concerns different usage for the aircraft. For many conventional airliners in European or US service this seems to have limited appeal since their operations are, for the most part, entirely uniform. Certainly, the aircraft have varying load patterns and sometimes have large numbers of unfilled seats. The airlines constantly seek ways to improve their load factors. Those airlines with extremely focused routes, such as budget airlines, generally have better load factors than general service airlines. However, in both cases the argument for a modular approach seems to be uncertain.

The concept is more relevant to aircraft with varying demands, that is to say operating from isolated strips and having to meet a number of different requirements, or aircraft operating throughout the year having to deal with snow, land and sea operations, as might apply in parts of Canada, for example. This has been the philosophy that has prompted the design of the Gevers Genesis which was developed to operate selectively on all three surfaces. Other versions might include an optional cargo/passenger layout or something between the two, or an optional passenger/fuel/water layout, or a long/short range aircraft choice. Each of these has implications for the optimum design of aircraft and modular approaches might well be economical if presenting these choices would do away with the need for another aircraft to be purchased. Keeping the weight and cost overheads of modularity as low as possible is clearly a challenge. These overheads arise from the provision of additional fixings and strong points that, on an integrated design, would be redundant. The removal of engine modules (for their replacement by a more role-suitable engine) would be relatively straightforward but the exchange of load carrying sections would be more difficult. An extreme suggestion was to modularise the passenger space down to either single, or a few passengers. The conceptual benefits of this would perhaps lie in loading time and in tailoring the capacity to the number of passengers.

Such passenger pods would need to be attached to the main airframe in a way that maintained aircraft structural integrity and that would in practice probably, although theoretically not necessarily, have the main load paths running around the pod constructed zone. This would allow the pods to provide for their own structural security and would also imply that services for passengers such as heating, ventilation, pressurisation, in-flight services, etc. would need to be connected to the aircraft either via each pod individually or through a number of pods.

One of the benefits foreseen for passenger pods is that they could be used to transport passengers and their baggage from a remote point —often the home — directly to the aircraft assembly point. This would imply a possible transformation of the airport operating structure and might save very large sums of money as a result. From an aircraft operating perspective, however, the integrity of these pods would need to be assured in respect to key parameters. These might concern the fixing points, service connections, outer skin, and pressurisation safety margins, etc. This argues against individual or distributed ownership except by agencies able to maintain the pods correctly.

At a lower scale, an example of modular design concepts is the idea of the personal seat. This imagines a seat unit that provides for the standard support of a passenger – i.e. connections to in-flight services etc., a luggage container and in-flight ready access supplies. The seat thus becomes the travelling support module for the passenger and can be transported by different means and transferred from one to the other and then to the aircraft where it would clip into a prepared docking station in the passenger compartment. In the aircraft it would require to be plugged into the supply system for entertainment etc. but would do away with all other check-in processes because the seat and its contents would be checked-in and security cleared as a unit.

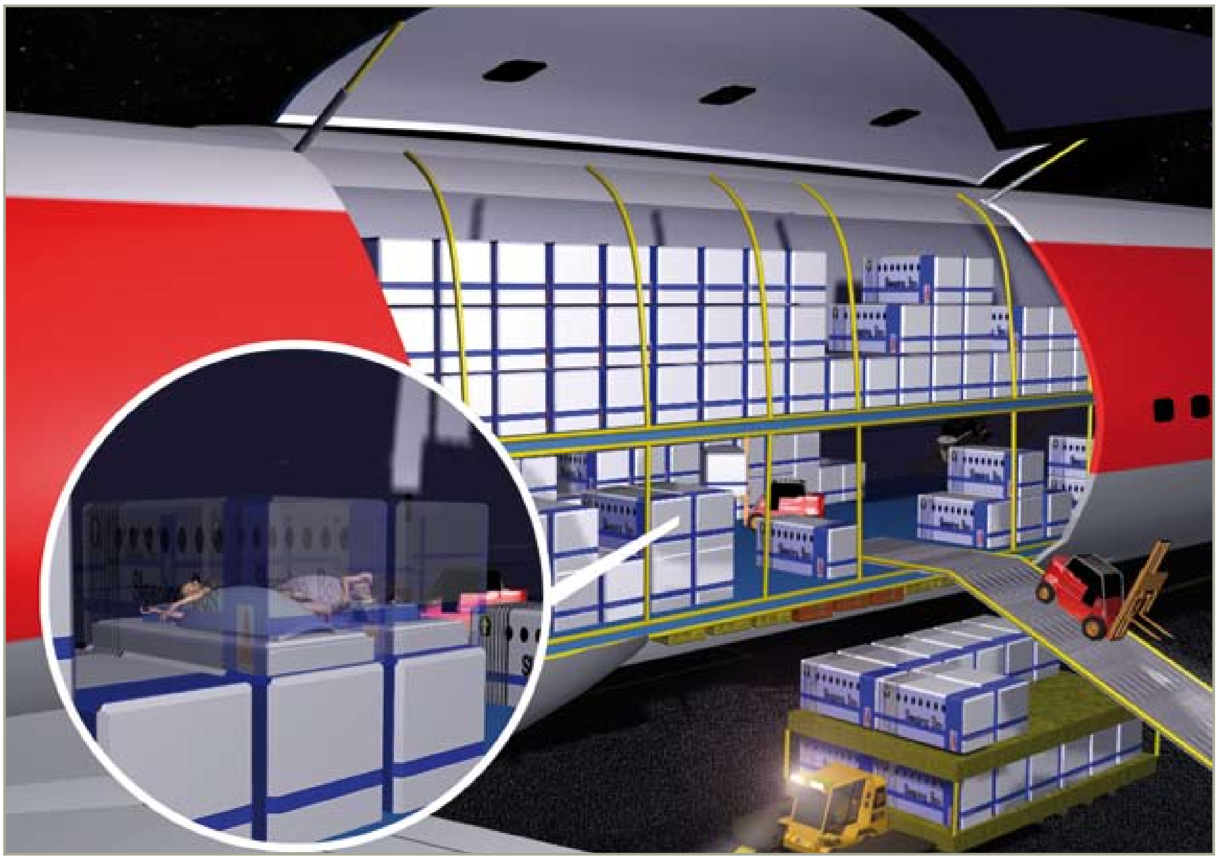
Morphing is an entirely different concept but with a somewhat similar end in mind. It envisages the use of flexible, moveable or adjustable elements of the structure to change the configuration of the air vehicle in flight. Among the simplest expressions of this idea are the several swing-wing aircraft that are in service. But more sophisticated means are also possible. The United States Defence Advanced Research Projects Agency (DARPA) has a number of projects concerned with aircraft structures and envisages a mixture of mechanical linkages and flexible skin structures to achieve much greater adaptation than simple wing sweep-back changes. The Gevers Genesis incorporates an extendable wing in its concept that would allow cruising to take place with a better wing form than the extended wing, and make it more suitable for landing and take-off. Various forms of adaptable and flexible materials are being researched. To date, no morphing designs for large commercial aircraft have been flown.

The passenger experience

Passengers in the late 21st Century may be expected to enjoy a very different experience from that of today, if some of the ideas in circulation come to pass. These ideas are driven by concerns for reducing the carbon footprint of the air traveller and by a desire to reduce the difficulties involved in reaching and boarding aircraft and to encourage an altogether less stressful journey experience.

The sleeping passenger

This idea is based on the idea that passengers will be able to be administered a drug which will have the effect of inducing gentle and harmless sleep for all or most of the flight. The drug would need to be non-addictive, harmless, with rapid or predictable sleep following its administration and rapid, anxiety-free and alert waking on administration of a signal or injection. The concept of drugs which could be taken by passengers or administered by airline staff would break new barriers and require careful controls not to speak of the safety testing that would be involved.



The benefits would lie in an experience less stressful for many passengers, especially on long flights, and a reduction in in-flight services. With suitable cabin design, passengers might be able to use full horizontal beds in tiers. These would prevent problems with deep vein thrombosis and permit a comfortable and relaxed sleep with very similar cabin volume to a seating arrangement for the same number of passengers.

Combined with the modular passenger pod concept (see 4.3) the passengers could board even before reaching the airport and pass through boarding formalities already in a state of oblivion.

The transparent cabin

In contrast to the concept above which would be feasible with no cabin windows at all this concept envisages a totally transparent cabin wall and roof. At present, high strength materials to achieve this do not exist but the transformation in passenger experience would be remarkable. The sense of being on a sort of magic carpet flying through the air could be a wonderful new experience for many passengers. For some, the experience might be altogether different and alarming, and therefore a quite unwelcome one.

Practical difficulties that would need to be addressed start with the materials to make it feasible without significant weight increase. Research would be needed into areas ranging from the nature of transparency and the possible modifications that might be possible, to the efficient materials of the aircraft pressure cabin. Given that such material might be developed it would also be necessary to study how many of the services presently out of sight behind the side walls and roof of the cabin could be routed to avoid these areas. The reaction of the material to sunlight and radiation might also present problems; making passengers too hot, to brightly lit or, at worst, susceptible to increased and dangerous levels of solar radiation.

The windowless cabin

Quite the opposite effect is envisaged by the windowless cabin. In this idea the passenger experience is enhanced by virtual reality images of flying instead of having widows to look out from. The idea is especially interesting against the studies being done on blended wing aircraft where many passengers would necessarily be seated well away from any windows. Given the continued rapid increase in the capabilities of games consoles, virtual reality simulations and all things electronic, the concept of an immersive experience based on artificially provided content is not perhaps very far away. The content supplied could vary, of course, from simply representing the flight in progress to representations of flights at different altitudes, and even over different terrain. Moving from the field of flight to a wider range of entertainment is an obvious progression and the repertoire of possible programs is effectively limitless.

The benefits would rest very largely with the passenger but the absence of windows might also provide increased flexibility of design and layout to aircraft manufacturers.

Multi-modal service

The customer will demand seamless travel from destination to destination. In future, travellers will also demand one single ticket that entitles them to make the total journey independent of the travel mode or operator. If the traveller is obliged to use different transport modes, they will demand multi-modal solutions that are time efficient and convenient. Aviation has been kept more or less separate from the multi-modal transport discussions, up to now, but this will have to change; air transport should be seen as one of the building blocks of a global multi-modal transport system. One of the important issues in multi-modal transport is the requirement for easy transit and avoidance of repackaging. This is also true for the cargo market. Containers used in aviation are different from the ones used in other transport modes. This is partially because aircraft fuselages are round pressure vessels, which require that separate containers are designed to be stored in the round cargo bay. Furthermore, the containers used in aviation are lightweight. Containers used in other transport modes are designed to be strong and heavy, to be stacked and to be stored in an unprotected harsh environment.

Multi-modality would be enhanced if the same type of containers could be used in all types of transport modes. New aircraft configurations like the blended wing body aircraft would allow the use of rectangular containers that could also be used by other transport means, without the need to repack. A compromise might be to design air containers that could simply be stowed as a complete unit inside a standard land container to provide the additional protection and to fit the land standard fixings.

One could imagine the use of a family of standard containers adapted to the different roles foreseen. The universal cargo containers could be made bomb proof as has already been demonstrated by containers made of laminated metal like Glare®. The smallest type of cargo container could be loaded onto small lorries which could service inner city distribution points. Larger containers could be used in shipping, trucking, as well as aviation. The passenger container could come in different sizes and be transparent. It could seat different numbers of passengers depending on the size of the container. There could be room to stow luggage and personal belongings in the container. Containers would be adapted for use in aeroplanes, on busses, trains and other transport modes. Airline passengers could be collected at different locations in different cities and be transported in these containers from the pick up points to the airport.

If need be, there could be a transfer point in between the pick up point and the airport or seaport, where passengers would change container according to their final destination. Such a system is already common practice in holiday coach travel: the passengers are picked up at different locations and transferred to a common transfer location where passengers seek the coach to their final destination. A similar setup could be followed using the passenger containers. With these containers, a multi-modal pick-up and drop-off system could be created. The containers would be loaded on the aircraft as soon as they arrive at the airport and connected to the aircraft utility systems. Containers would also be connected to corridors inside the aircraft that would give access to general facilities such as restrooms, bars and entertainment facilities.

Self-load baggage

Being parted from one's baggage is just one of the stresses of modern travelling. The effort that some passengers make to avoid checking in baggage is just one of the symptoms of this stressful feeling and the perception that it involves delays, lost or delayed bags, and lost or stolen contents.

One idea to address this is to go with the sentiments of the passengers and allow them to take their baggage with them onto the aircraft. By redesigning the interior of the fuselage it could be possible to arrange for vertical luggage bays which can be loaded directly by passengers. Alternatively, the redesign of the baggage loading process could position the cargo container in a place that is accessible to the passengers, who could load their own bags and similarly unload them at the destination.

There would be disadvantages for the airports in that their baggage-centred process would need to be re-aligned to become a passenger-centred one, no doubt at some cost. However, the benefits to passengers might be considerable, even if these benefits exist only in the mind, given the low percentage of bags that would actually get lost. Detailed process engineering would be needed to ensure that the benefits that passengers want, security, time saving and convenience were actually delivered by any new process. If the aircraft were to be redesigned, the issue would be of preserving the pressure envelope without sacrificing too much of it to baggage storage at the expense of passengers.

Boarding through multiple doors

This idea is similar to the current provision of multiple doors and envisages many doors with simultaneous boarding and disembarkation in parallel streams. In theory, passengers would board along an air-bridge dedicated to their entrance and appropriately signed to prevent confusion. They would join the aircraft at a point immediately adjacent to their seat and would be able to become settled much more quickly. On wide-bodied aircraft these doors might be on both sides of the cabin to permit easier boarding.

For the aircraft manufacturer, providing more doors will extract a price in the weight carrying capacity of the aircraft and upon cost, both of which would need to be eventually passed on to the passenger.

The airborne hot-desk

The number of business travellers increases less rapidly than the number travelling for leisure. Nevertheless, the pressure on individual business travellers grows, with competition increasingly being fuelled by the electronic devices that enable businessmen to operate from anywhere in the world. This is increasingly more so, but the situation is progressing at a slower rate in the air than on the ground.

A new and important step in this transformation will be to install a genuine "Hot Desk" facility for the ordinary business traveller. This would enable him to work as normal whilst airborne with access not only to the internet and e-mails, but also to a useful range of commercial office software. Almost as important would be access to his own files and records as fully as he would have in any terrestrial situation. Where cost is no object, installations for such facilities can now be provided. The challenge will be to supply them at a reasonable and commercially acceptable cost.

Relevant technologies will include secure broadband access from the aircraft, the access to appropriate software, and secure deletion of private files. All these are foreseeable within present or forthcoming technologies.

The air traveller

For most passengers, travel by air represents a period of time spent merely getting from A to B. The faster it can be achieved, the better. The less that it interferes with normal daily life, the more the passenger appreciates it. However, with people looking for new experiences and with limited time on their hands, a new or rather re-invented kind of passenger may emerge, the air traveller. This kind of traveller travels by air for the experience it offers and the places that it allows him to see. In the 1920s travel by the great German airships was an experience in itself and passengers considered themselves to be fortunate to be able to take part in the Graf Zeppelin's world tour in 1929.

Today we can consider this renewed interest in the world around us, and the chance to see it before it suffers, inevitable change. The passengers would be provided with a high level of luxurious accommodation on board with every opportunity to move around in comfort.

Meals may be taken at tables rather than in seats and these may be placed to give excellent views of the passing landscapes. Of course, the aircraft will fly at relatively low altitude perhaps as low as 1 500 m where this is possible. For this reason, the aircraft would be designed for slow (perhaps 120 knots), quiet flight, possibly with shielded propellers mounted above the high mounted wings. The passenger cabin would be a single aisle design with every passenger able to enjoy a good external view. This view would be augmented by forward viewing from the front cabin and by an array of real-time video cameras feeding views into the cabin. These could be combined with lecture presentations on the geography, flora and fauna of the area. When possible, the concept of transparent cabin section (see The Transparent Cabin above) would be employed to add to the experience. Few new technologies are necessary to bring this idea to deployment. The obstacles would be the assessment of commercially viable demand and the investment in suitably designed or adapted aircraft.

No cabin crew

At present there is about one cabin attendant per 50 passengers on board commercial airliners. Cabin crew has an important function to guide passengers in case of emergency and to serve the passengers during the flight. But crew costs represent a substantial part of the Direct Operating Cost of the aircraft. Cost efficiency could be increased if no cabin crew would be needed. For passenger service in smaller aircraft, the crew could be replaced by automated systems that would use robot type technology. In larger aircraft the passengers could stroll around and help themselves to whatever service they desire, being served via a galley wall by robotics.

In larger modern aircraft, the safety drill is already explained via a video presentation. A different approach could be that the passenger receives the information via his or her cellular phone. This phone or a more advanced personal communication device would be also be used to guide passengers around the terminal buildings of airports. In case of an emergency, the passenger would be provided with safety instructions via the personal communication device. For those who do not have a personal communication device, the device would be provided by the airline.

Globalised ATC

A need for pilots?

New procedures and tools are introduced based on the traditional idea of controlled airspace, where end to end planning of traffic flows is an important element. So called 4D trajectory planning is aimed at a seamless flow along airways and arrival/departure at airports. It is based on an automated control loop between the aircraft flight management system (FMS) and the Air Traffic Control computer for IFR traffic. If such automation is the way forward, there is no need for pilots on commercial IFR flights anymore. Aircraft can be flown automatically under ground control. (There may be a need for a safety pilot to reassure the passengers and to act in case of emergencies not foreseen by the software. This safety pilot could attend to other duties such as cabin service during the flight.) The question remains, if such a system based on automation of the traditional ATM concept is flexible enough, how should unscheduled traffic be handled? Can central computers deal with large amounts of traffic data? How should control from one ground station to the other be passed on? What about intercontinental traffic planning, as international traffic is more dependent on variable jet steam velocities and their 4D trajectory is difficult to predict. If flight control is fully automated, who is liable in case of an accident? Can older aircraft be upgraded to shorten the transition time to fully automated flight?

Free (IFR) flight?

New technologies are now available that would enable totally different concepts. Satellite based navigation, communication and surveillance enables precise navigation and broadband communication, making radar (and mode S) communication no longer necessary. The aircraft now has a reliable navigation tool and thanks to advanced communication data-links, can see all relevant traffic. In combination with onboard systems like collision avoidance systems (ASAS), automated weather updates, ground proximity warning systems, enhanced vision systems and wind shear/vortex warning systems (which can be integrated into a single, easy to interpret display), the pilot can obtain total situational awareness. The function of a controller would be at best to act as a safety monitor for en-route traffic and to ensure that traffic jams are avoided near airports. However, airlines may manage their own slot priorities at airports via CDM systems. So the radical alternative is to rely totally on the pilots without the need for controllers or control centres.

Non-controlled airspace

The air transportation system is going to change. Aeroplanes will become very silent allowing 24-hour operations at airports, even in the vicinity of big cities.

ATS may also shift from scheduled towards more unscheduled operations. There may be a variety of flying vehicles; like personal air vehicles, air taxis, business jets, charters, unmanned aircraft (flying under ground command or flying a pre-programmed track), dedicated cargo planes, and planes from regular airlines using a Hub and Spoke system as well as direct routing to both primary and secondary airports. Inter-city and intra-city traffic will be using VTOL aeroplanes, whilst civil and military aviation will share the same airspace.

Strategic 4-D planning or speed control becomes impossible as trajectories of all this traffic are unknown. Reserving airspace for particular applications would create artificial shortage and should be avoided.

In such a system, the prime concern is to ensure that mid air collisions and traffic jams near airports or landing sites are avoided. Thanks to secure satellite CNS and intelligent anti-collision systems, aircraft would be unable to collide in the air or with the ground. Flight control and collision avoidance would be automatic by introducing intelligent systems on board. In certain cases, manual override would still be feasible as IFR operations are like VFR operations with total situational awareness based on network-centric communication tools. Onboard navigation systems will select the best route, and ensure that flying through severe weather is avoided. Much can be learned from the route planning and navigation devices currently available for cars.

Airport shortage will be partially offset by introducing different airport layouts, the Metro liner, dedicated cargo airports, floating airports, and separating take-off and landing and VTOL-aircraft. Scheduled air traffic would be, "de-peaked" as much as possible. The restructuring of the transport system, by bringing air and ground management under one umbrella, will help in this respect.
If insufficient airport-slot capacity remains, slots will be sold to the highest bidder. Slots may represent a scarce commodity and thus have a price. Such an economic mechanism will stimulate operators to look for clever alternatives to offload their passengers.

Global ATM

By replacing traditional procedures and systems not by automation but by intelligence, a totally different air traffic control will emerge. Control will be back where it all started: inside the vehicle.

We need to ensure that all aircraft in the world will be equipped or retrofitted with the same standard equipment. If large-scale production of equipment can be achieved, the equipment price will be low. Current developments in onboard equipment for air taxi aircraft are already leading the way. Human factors will have to be given more attention than in the past. Certification will stay an important issue. We need to organise a world-wide consensus on the future of air traffic control. We need to think of different concepts to help cope with a future containing diversified air traffic.

Subordinate concepts

Introduction

Many of the ideas collected in this survey concern the design of the aircraft, or have implications for its design. Rather than present them as a simple list of disparate ideas, they have been collected together under eight headings. These range from new ideas for flight mechanics (under Global Flight Concepts) to the induction of sleep to give passengers a stress-free flight (under Passenger Experience). Several of the concepts examined in other principal sections have implications for the design of the aircraft, whether in the Cruiser/Feeder concept or the Airport of the Future. In general, where individual subjects have been treated at length in other sections they are not repeated here.

We have become accustomed to the standard airlines of the early 21st Century. They have a familiar form and most of them have the familiar characteristics of large twin engines, a cylindrical fuselage, a lower freight bay and upper passenger compartment, swept back wings and a tricycle undercarriage. Some argue that this form is the conclusion of evolution and that it simply demonstrates the limiting form of the idea. Others take the view that any form is only the product of the circumstances that produced it and if these change, the evolutionary form will change and can be altered. The ideas presented here follow this path.

Prompted by the pressure for greater environmental sensitivity, some ideas focus on ways to make dramatic, or at least important, savings in the amount of fuel used by the world's airliners. Previously dismissed contributions regarding greater economy of fossil fuel lie behind the thinking of several concepts.

The glider-like airliner

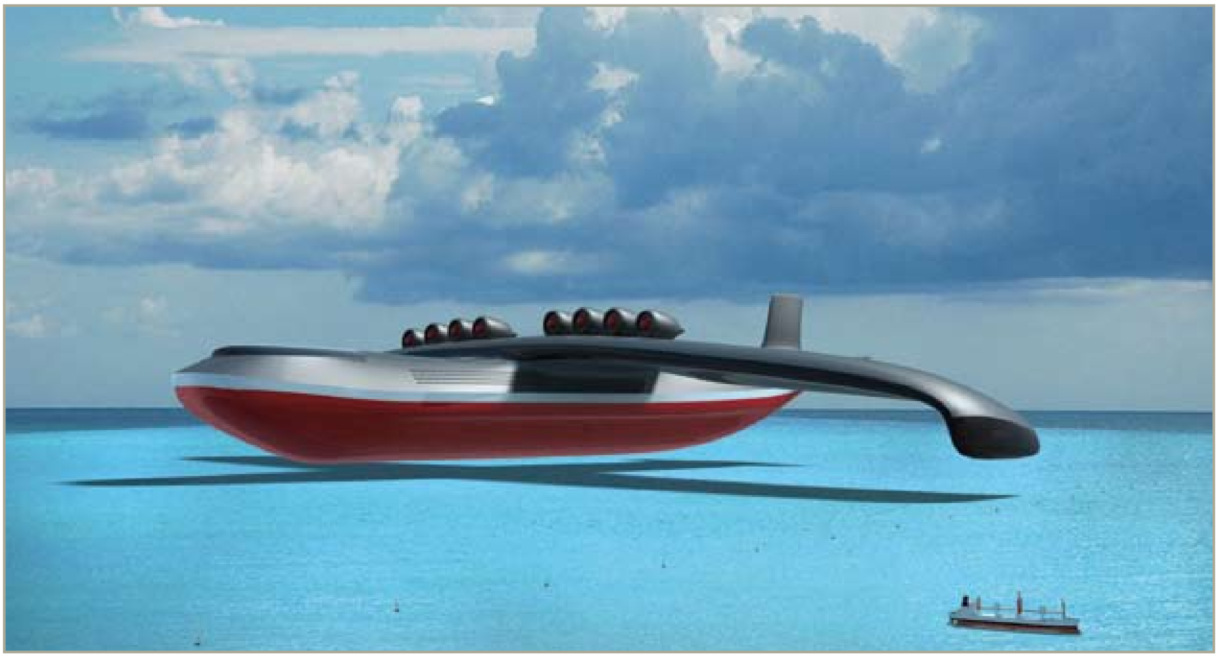
Gliders possess very high aspect ratio wings. These low drag wings allow them to sustain altitude in the lightest of upward thermals (about 1 foot per minute) and thereby to carry out long distance flight on no fuel at all. Their glide ratio is extremely shallow, in the order of 1 in 55, compared to a typical airliner of 1 in 15 (Boeing 747). Powered gliders are somewhere between a conventional aircraft and a glider. Their small engines can be used to gain or to sustain altitude and the consumption of fuel is still only small.

The concept is for airliners with some of the characteristics of a powered glider. It would have high aspect ratio wings and be fitted with substantial engines for climb out, but would be much less powerful than those in current use. Its cruising speed would inevitably be much lower, perhaps in the M0.4 range. Take-off speeds would be lower and runway lengths much reduced. The normal mode of operation would involve using the engines but cruising power demands would be much lower. A glide ratio of perhaps 1 in 27 would produce a hybrid, with many of the advantages of the glider while retaining most of the flexibility of the modern airliner. The benefits are mainly in the consumption of fossil fuel. A 200 seat airliner on a 1 000 nm (nautical mile) leg will use something like 10 tonnes of fuel. A glider-like aircraft of the same capacity would use perhaps an eighth or a quarter of this amount. The lower speed of the aircraft brings some disadvantages: the aircraft is less able to earn revenue and it offers slower and therefore less attractive journey times. However, it would be a cheaper product to produce and for medium-haul, the extra journey time will not be hugely significant (the change from say M0.83 to M0.4 would add about 30 % to total door-to-door journey times on a 1 000 nm leg).

> **‘A 200 seat airliner on a 1 000nm (nautical mile) leg will use something like 10 tonnes of fuel. A glider-like aircraft of the same capacity would use perhaps an eighth or a quarter of this amount.’**

Wing in ground effect (WIGE) craft

These WIGE craft have been produced for many years, most notably by the former Soviet Union. They promise considerable savings in fuel through operating near to the surface (within about half a span) and through gaining from the ground effect of the airflow over the craft. Large and small craft have been shown to be feasible. A body of knowledge already exists for their design and construction. In the era when most WIGE were subject to experimentation within the former Soviet Union, the considerations regarding fuel saving were of a different kind to today. It may now be the time to re-examine such WIGE craft and to adapt them for commercial operation. The potential



benefits lay in their fuel efficiency. For a 200-seat craft over a 1 000 nm journey the fuel saved might amount to 50-60 % or 5 or 6 tonnes. The disadvantage to these craft is that speeds are generally in the range 150-250 knots and the routes for their operation must be suitable for very low flying craft i.e. either sea-lanes or empty land. Technically, the craft work satisfactorily when properly designed although a natural disposition towards pitching needs to be carefully considered.

High-speed blimp

The technology of lighter-than-air craft has progressed substantially since the heyday of the great German Airships of the 1920s. At the most obvious level it is no longer necessary to use hydrogen as the lift gas with its attendant dangers. In recent times, several companies have come up with concepts for airships for special purposes including heavy lift operations. The idea put forward here is for an examination of a high-speed airship which might overcome the disadvantages of the relatively slow speed (around 100 knots) of conventional craft. The essence of a pure airship is that the lift and thrust components of flight are provided for quite separately. Lift is from a large gas enclosure and this lift is almost independent of speed. Thrust is provided by a number of engines which do not provide any component of lift. With modern designs, these conventional approaches have been questioned. The very modern Zeppelin NT has rotating engines that can contribute to lift as well as forward speed, nevertheless, the speed is 125 km/hr in level flight. The Ohio Airships Dynalifter® is a hybrid craft with wings that contribute to lift and control as speed is achieved. A substantial fraction of the weight is lifted by the wings and this is claimed to be a benefit in landing since the craft will sit securely on the landing ground once at rest. Speeds of 100-200 knots are forecast for this type of craft. The Cargolifter heavy lift airship was one of the concepts designed by the company carrying up to 160 tonnes at speeds up to 90 km/hr. Cargolifter suffered insolvency in 2002 and the present fate of the project is uncertain.

It is certain that new technologies make the construction and use of airships more practical. With hybrid technologies, some of the handicaps of the format may be overcome. In trying to achieve very high speeds there will continue to be a compromise between lift, size and construction since an envelope of minimum cross-section would be too long to be practical. Similarly, an envelope of compact length would represent a considerable cross-sectional drag.

Flying boats

The days of the great flying boats seem to be well gone. The unexplored potential of the Spruce Goose, the might of the PanAm Yankee Clippers, the sturdy service of PBYs and Sunderlands all seem to belong to the pages of the history books. However, as we look at the new challenges of the future there are reasons to think that the second age of the flying boat may be just around the corner. We hear, for example, about congestion at hub airports, and we know the opposition that is raised to any airport extension. We know also that these reactions are set to get worse and not better.

New technologies could be applied to new designs of flying boat and might include better resistance to corrosion, more controlled approach and landing, and more convenient entry and exit arrangements when compared to their predecessors. Very large aircraft could be considered given the space and water surface for landing.

Flying lower and slower

A high cruising speed has always been a design parameter when developing airliners. High speeds mean high productivity and thus low operating cost. Turbofan engines are optimised to operate at high altitudes. Large aircraft are optimised to fly at speeds of up to Mach 0.89 and to about Mach 0.80 for regional aircraft. Initial studies in the past have indicated that a regional jet seating 100 people and powered by a turbofan engine, flying at Mach 0.77 at 37 000 ft, would need 82.5 minutes to fly a 400 nm mission. If the aircraft was powered by a counter-rotating prop-fan engine flying at Mach 0.72 at FL 31 000 ft, the time required would be 83.4 minutes. This represents an increase in time over a 400 nm stretch of 1 %. Yet fuel consumption would be 35 % lower and NOX emissions are estimated to be 50 % lower. The effect of flying at lower speeds on long-haul flights would of course be more substantial. A trade-off between flying slower versus the longer flying time and the consequences for total fuel consumption need to be calculated.

Flying at high altitude creates contrails. It is believed that contrail formations contribute significantly to global warming. The formation of contrails is dependent on ambient atmospheric conditions. Contrails start to appear when the outside temperature is less than -40 degree Celsius. To avoid contrails, aircraft would need to fly substantially lower especially during wintertime. The temperature conditions can vary significantly between regions and may vary on a daily basis. Consequently, some have suggested adapting preferred flight altitudes in flight plans on a real time basis to minimise contrail formation. However, flying above 40 000 ft also reduces contrails as the humidity level at or above that altitude is low, although flying at such altitudes may have other negative effects as a result of other emissions. The current generation of aircraft is not well suited to flying at lower altitudes such as 20 000 ft. Flying lower would result in longer journey times and hence more fuel burn. On a 6 000 nm journey, this could result in, for some types of aircraft, a flight time of one to three hours more and up to 30 % to 60 % more fuel-burn and hence CO^2 emissions, depending on the flight altitude. Such severe consequences are difficult to accept with current aircraft.

Different fuels will not mitigate the contrail problem, except in cases where nuclear energy could be used to power aeroplanes. The alternative would be to design aircraft and engines that would be optimised to fly at lower altitudes. Trade-offs are needed to demonstrate the optimum environmental impact of flying high and fast versus low and slow. These studies need to take a full systems view, taking into account total carbon emissions and NOx, as well as the investment return on the aircraft. Flying at lower speed or altitude goes against the long-established trend in air transport as it results in longer journey times, loss of efficiency and the need to procure more aircraft. On long-haul flights, it may even make stopovers necessary again unless in-flight refuelling is introduced. However, if the protection of our environment calls for this concept, we should seriously consider changing technological developments in that direction.

UAVs and autonomous flight operations

During recent years, UAVs (uninhabited aerial vehicles) have become common in the military domain. UAVs in the military are used for dull, and dangerous missions. Two types of UAV vehicles exist: UAVs controlled by an operator on the ground and UAVs that fly autonomous missions. The cost of a crew is a substantial part of the Direct Operating Cost (DOC) of airliners and their replacement by automated systems would be an attractive proposition. However, there are serious safety concerns.

Nowadays aircraft can auto-land and fly using the autopilot. However, technology is not foolproof and human intervention is needed from time to time to reset the systems. One could imagine a future in which planes would be flown in a totally automatic mode. Advanced self-separation and automated station keeping, auto-takeoff and auto-land will be feasible. One could think of a safety pilot who would monitor the onboard systems as an interim phase before accepting fully pilot-less aeroplanes. Manual override capability would be available to the ground-based operator. The introduction of this system is related to the reliability of systems, to safety concerns and to security issues. At no time should terrorists be able to intercept the communication with the aircraft and take over their control. Highly secure data links would be needed to ensure these situations cannot occur. The introduction of pilot-less aircraft in civil aviation could be feasible at first in all cargo UAVs. There are substantial cargo movements in Europe. In the north/south direction, the cargo has to pass over the Alps and the Pyrenees. In the east/west direction surface traffic has to cope with transport infrastructures in the East that are not yet of the same quality as in Western Europe. As rail infrastructure is limited and passenger trains have higher priority than cargo, the average speed of cargo rail is extremely low. Inland shipping is an option but is only slow to re-develop. Therefore, trucking has become the most favoured way to ship goods. However, European highways are already saturated and will be completely blocked in a few years. Unless the personal flying vehicle is introduced quickly, the most desirable option will be to ship goods by air. Aerial freighters could fly standard routes that could easily be handled by UAVs.

The idea of uninhabited aerial cargo vehicles (UACVs) is not new. Their development should take into account the certification related issues. How to ensure that the vehicles will operate safely? How can we track the aircraft and who would be able to take over manual control? What will be the importance of the interference with other traffic? What about the liability issues?

One possible scenario is to fly these aeroplanes at night and to create special flight corridors for cargo aircraft. These could use direct routes and be monitored and controlled by a single authority. The UACV would fly standard patterns. There would be an automated station keeping and avoidance system installed with autonomous features to fly holding patterns in case of a disruption in traffic.

The next step in flight automation could be the autonomous small flying vehicle. The difference between the cargo liner and the personal vehicle would be that the cargo-liner would fly the same pattern every day whilst the personal aircraft would need to be very flexible. If the technology proves to be safe and reliable even large passenger aircraft could become pilot-less. Here the key word will be safety perception rather than technology.

Vortex control

Vortices have been present behind aircraft since the beginning of aviation. As aviation has developed so has the understanding of the physics involved in the generation of vortices. The importance of vortex management lies with the central factor that determines their strength, the weight of the generating aircraft. Therefore, as we move to heavier and heavier aircraft, the problem becomes more acute. The forces involved are considerable with vortex circular wind speeds of up to 300 ft/sec being generated; they comprise twin contra-rotating spirals of air that rotate in the under-wing to over-wing direction at each wing tip.

Vortices are important to airport efficiency and safety. Where large heavy aircraft are using the airport, the avoidance of vortices can become a limiting factor to airport capacity. This occurs by the application of longer separation distances between heavy leading aircraft and lighter following aircraft. Where inadequate allowance is given to the possibility of vortices affecting following aircraft, accidents can happen, with disastrous results given the low altitude of the event. Vortices are especially more serious in the conditions that apply to landing — heavy, low, and slow.

Vortices also occur in flight but they sink and fade away normally within the clearance distances that are usually sustained. They become more important when concepts such as formation flight and linked aircraft are applied. For these reasons, research to understand, to modify and ultimately to control vortex formation has a high priority on both sides of the Atlantic. The introduction of the A380 will raise new issues to be resolved as it leads the field in weight. European research programmes like the AWIATOR programme in FP6 has vortex management at its centre.

In the longer term, the control of vortex formation and the ability to modify its behaviour might also bring new opportunities. Arranging the vortices to be favourable to formation aircraft would bring the concept of grouped flying very much into play. Flying onto large structures such as imagined with the Airborne Metro would require this phenomenon to be understood extremely well.

Invisible aircraft

Airports are centres of economic activities. As a consequence, airports attract business activities, both directly related to the air station function and businesses that are dependent on air freight and easy access to air transport. Consequently, many people want to live near to their place of work and thus near to the airport. Cities and airports expand and because of the increasing air traffic, there are complaints from the people living near the airport about aircraft noise, pollution and smell. Experience has shown that when traffic increases even at constant noise levels due to improvements in aircraft technologies, the complaints about nuisance from aircraft noise tend to rise. Noise is therefore not an absolute issue but a question of perception.

One solution to alleviate the problem is to make aircraft invisible and to make them silent. In the military domain work is being carried out to create visual stealth. The active camouflage technologies range from using light to illuminate the aircraft, by using fluorescent panels amongst others. Research is also focused on electro optical camouflage using electro-chromic polymer materials. Aircraft could be covered with a coating of LCDs. Photosensitive receptors scan the surrounding of the aeroplane and a picture is displayed on the LCDs. This technology would make the aircraft virtually invisible as it blends with the surrounding. Anti-noise technology would be used to counter the noise of the aircraft and tests are already performed to see if the technology can be used to compensate for aircraft noise inside a house. The technology could be expanded to create anti-noise in areas located near to the departure and arrival tracks at airports.

Aircraft themselves can be made silent by avoiding airframe noise produced by high lift devices, the undercarriage and aircraft cavities.

Hypersonic and space travel

Current methods to launch men into space and to bring them back to earth are extremely expensive and dangerous. New ventures like that by Rutan could make space travel feasible at an acceptable cost, but the idea of using a space plane to visit hotels in outer space or densely populated stations on Mars is still a long way off. Another issue is travelling to destinations on earth at higher speeds. The sound barrier seriously restricted travel to subsonic speeds, with only Concorde flying at Mach 2 on a regular basis, requiring substantial amounts of power and fuel to overcome drag in the atmosphere. Therefore, Concorde was expensive to operate and only accessible to the lucky few. Will it be feasible to fly even faster than today to several destinations in the world at reasonable cost? Will hypersonic airliners, flying five times faster than the speed of sound, bring us to any destination on the globe in a few hours? The technology is (almost) ready. New supersonic ramjet technology (scramjets), using air breathing propulsion systems based on liquid hydrogen fuel would allow us to reach any place on the globe within two hours flying at Mach 10.

New methods of flight such as the wave rider method would allow airliners to ride on their own shock waves. The concept of Hyper Soar would lift an aircraft under its own power up to 40 km high. The engines would then be turned off. The plane would continue to accelerate to 60 km altitude and then fall back to earth. At about 35 km high it would "skip" on the upper layers of the atmosphere and be bounced back into space. Each skip would represent a 450 km travel distance and a trip between Tokyo and the western part of the US (10 000 km) would take 72 minutes, using 18 skip procedures. The inventors claim that this method would make travel twice as fuel-efficient as today's airliners. The question remains whether this could become a regular way to travel or just a fun ride as passengers would be subjected to zero "g" conditions and probably to several "g's" during the bounce.

We feel that such operations will not replace regular air traffic for a long time to come. The hypersonic aircraft will probably first be used in the military domain. Issues like propulsion, heat and safety need to be explored first before any use in commercial aviation seems feasible. However, if we succeed in attaining speeds of up to Mach 24, we could develop an aeroplane that could reach outer space stations, as this speed would represent the same speed as objects in orbit around the globe. Such a vehicle would probably need a combination of scramjet engines and rocket power.

Do we feel that space travel or hypersonic travel is likely to happen on a routine basis in the next 50 years? Probably not, unless major steps in new technologies come along that would allow for an efficient, safe and a comfortable (1-g) journey.

Appendix C:

Short List of the 23 Projects Selected for Assessment.

No	Title	Description	Overall Score
10	**Airborne air stations**	Floating air-stations in mid-air as transfer points or with direct ground to air connections.	16
43	**Cruiser/feeder concept**	Large semi-permanently airborne cruisers are a feature of an airborne metro system. They are fed by ground-to-cruiser aircraft. The aim is greatly reduced carbon fuel use by some combination of nuclear cruise engines and short range feeder journeys.	21
72	**High-altitude airport**	High fixed tower offering benefits of increased weather tolerance, reduced ground noise, reduced footprint, etc.	17
22	**Ground Powered/ Assisted launch systems**	A generic class including catapults, maglev rails or other uses of ground power to assist launch.	19
26	**Nuclear power**	Self explanatory aim but one which can be combined with other ideas – e.g. the cruiser/feeder concept.	19
73	**Chain of aircraft**	Allows aircraft to be rigidly or flexibly assembled in small clusters to benefit from the overall reductions in power. Take off and fly as a locked set.	22
12	**Personal air transport system**	Meets the on-demand trend. Gives optimised transport routes. Includes ATC for PTS with perhaps limited control of heading, height etc.	19
13	**UAVs for cargo**	Self explanatory aim	13
14	**Ground effect aircraft over ocean**	Harnesses ground effect for inter-continental journeys.	16
24	**Teleportation**	Self explanatory aim	18
33	**Full-body scanning portals**	No need to have security checks. Passengers walk through scanning devices.	20

No	Title	Description	Overall Score
34	**New ID techniques**	Walk-through corridor enables ID to be checked in real-time.	19
58	**Business models**	Offers a range of different business models that provoke a different set of behaviours. Could include new models for airlines such as Timeshare Ownership, Co-operative Ownership, etc.	21
70	**Morphing airframes**	Allows the airframe to change its characteristics in a controlled manner.	18
74	**Floating airport**	Utilises the sea to provide space for major new hubs.	15
76	**Plasma aerodynamics**	Enables high speed at lower energy cost.	14
81	**Ramping Runways**	Assisted Take-off and Landing Runways that assist operations by exchanging potential and kinetic energy.	16
85	**Nano-technology**	New surface materials etc.	12
6	**Autonomous flight operations**	Relies on on-board ATC which may have become practical. May include autonomous sense and avoid systems.	15
7	**Glider-like aircraft**	Uses the attributes of soaring gliders for efficient flight. Fuel saving, smaller power units.	20
15	**Air refueling**	No need for long-range airliners.	16
18	**Modular cabin**	Meets a particular market for flexible flight by small groups or obscure point-to-point services. Removes weight from aircraft. Airport mechanisms to be defined. Loading modules of pre-populated cabin structures which lock together to form the flight vehicle.	16
23	**Tube Launch and land system**	Uses a ground powered "wind tube" to create a flying speed environment on the ground. Dispenses with undercarriage.	19
25	**Water as fuel**	Decomposition by e.g. laser and re-composition to produce net energy release.	17
53	**Modular built aircraft**	Manufacturing aircraft in a modular manner so that aircraft are made from a limited series of compatible assemblies. May be extended to reconfigurable concepts in which modules may be selected in the hangar to optimise the vehicle to the journey.	14
54	**Plug-in / out aircraft design**	An open system approach to aircraft system exchange allowing most systems to be unplugged and replaced with new, updated or differently specified systems.	14
67	**Wikipedia concept for innovation (Innopedia)**	An open contribution compilation of knowledge about innovative ideas. Would need moderating.	16

Appendix D:
Technology Areas of the Six Selected Projects

The ACARE taxonomy

The basic technology taxonomy used is the ACARE Taxonomy generated for the 2nd Edition of the Strategic Research Agenda.
In some cases, it has been necessary to add a small number of technology areas to cater for the areas that may need to be dealt with in the innovation process.

The areas suggested for study

There is no certain way of forecasting which technologies will need to be embraced by these innovative studies. It may be necessary to engage expertise in areas that could not have been foreseen at the start.

Nor is it likely to be helpful to propose that every technology area of the taxonomy should be proposed as a region for research. This would be a blunt instrument and would lack any kind of selection.

The technology sheet incorporated in this Annex is therefore a compromise. It proposes a number of technology areas that are most likely to be needed and the main focus of the research work is probably going to fall into one of these areas. That said, it is possible that entirely different technologies may be proposed as keys to the innovative designs being studied. It should be possible for these innovative approaches to be considered. The suggestions in this Annex are suggestions only and should not be used to exclude other well thought through proposals.

The Important Technologies:

Astera Taxonomy -OOB Part 2 Version

Flight Physics	**FLP**
Aerostructures	**AST**
Propulsion	**PRO**
Aircraft Avionics,+B208 Systems and Equipment	**AVS**
Flight Mechanics	**FLM**
Integrated Design and Validation (methods and tools)	**IDV**
Air Traffic Management	**ATM**
Airports	**APT**
Human Factors	**HFA**
Innovative Concepts and Scenarios	**ICS**

			Col E: Aircraft Propulsion after Gas Turbines	Col F: Globalised and Seamless ATC	Col G: The Cruiser Feeder Concept	Col H: The Use of Ground Power Sources	Col I: A Personal Air Transport System	Col J: Connecting People with Aircraft
1. FLIGHT PHYSICS								
101	**CFD**	Computational Fluid Dynamics			■	■		
102	**UAD**	Unsteady Aerodynamics			■	■		
103	**API**	Aeronautical Propulsion Integration			■	■		
104	**AFC**	Airflow Control			■	■		
105	**HLD**	High Lift Devices			■	■	■	
106	**WGD**	Wing Design			■	■		
108	**SCD**	Store Carriage and Release			■	■		
109	**WTT**	Wind Tunnel Testing/Technology			■	■		
110	**WMT**	Wind Tunnel Measuring Techniques			■	■		
111	**OPE**	Operational Environment			■	■		
112	**CAC**	Computational Acoustics						
113	**ENP**	External Noise prediction			■	■	■	
2. AEROSTRUCTURES								
201	**MMP**	Metallic Materials and Basic Processes			■			
202	**NMP**	Non-Metallic Materials and Basic Processes			■			
203	**CMP**	Composite Materials and Basic Processes			■			
204	**MAT**	Manufacturing and Assembling Technologies			■	■		
205	**SAD**	Structural Analysis and Design			■	■		■
206	**AEL**	Aero-Elasticity			■			

207	**BVA**	Buckling, Vibrations and Acoustics			■			
208	**SMS**	Smart Materials and Structures			■			
209	**SMT**	Structures Behaviour and Material Testing						
210	**INP**	Internal Noise Prediction				■		
211	**HAA**	Helicopter Aero-Acoustics						
212	**NOI**	Noise Reduction			■		■	
213	**ACT**	Acoustic Measurements and Test Technology						
214	**ASY**	Aircraft Security			■			
215	**AMP**	Advanced Manufacturing Processes			■			
3. PROPULSION								
301	**PER**	Performance			■	■		
302	**TPA**	Turbomachinery/Propulsion Aerodynamics						
303	**COM**	Combustion	■					
304	**ABP**	Air-Breathing propulsion	■		■			
305	**HTT**	Heat Transfer	■					
306	**NVR**	Nozzles, Vectored Thrust, Reheat	■		■			
307	**ECT**	Engine Controls	■		■		■	
308	**SIG**	Infra-Red and Radar Signature Control						
309	**APU**	Auxiliary Power Unit						
310	**FUL**	Fuels and Lubricants	■		■			
311	**ECL**	Engine Calibration						
312	**EHM**	Engine Health Monitoring	■					
313	**EXP**	Experimental Facilities and Measurement Techniques	■					
314	**CMM**	Computational Methods	■					
315	**EPD**	Emissions Pollution					■	
316	**ECP**	Energy Conversion Physics	■		■	■		
317	**ANR**	Aircraft Nuclear Reactors	■		■			
318	**MPT**	Magnetic Propulsion Technology				■		

		4. AIRCRAFT AVIONICS, SYSTEMS AND EQUIPMENT - Avionics and on-board systems						
401	**CSD**	Cockpit Systems, Visualisation and Display Systems		■			■	
402	**NAV**	Navigation / Flight Management / Autoland		■	■		■	
403	**WAR**	Warning Systems		■			■	
404	**EME**	Electronics and Microelectronics for On-Board Systems					■	
405	**SIN**	Sensors integration			■		■	
406	**FDR**	Flight Data/Flight Recording		■			■	
407	**CSY**	Communications Systems			■		■	
408	**IDN**	Identification					■	
409	**AVI**	Avionics Integration					■	
410	**OPT**	Optics - Optronics - Lasers - Image processing and Data Fusion					■	
411	**ELS**	Electronic Library System					■	
412	**HUM**	Aircraft Health and Usage Monitoring System	■		■		■	
413	**SMA**	Smart Maintenance Systems					■	■
414	**LTG**	Lighting Systems					■	
415	**ACS**	Aircraft Security			■		■	
		4. AIRCRAFT AVIONICS SYSTEMS AND EQUIPMENT - Power systems						
416	**EPG**	Electrical Power Generation and Distribution	■		■	■	■	
417	**PNU**	Pneumatic Systems				■		
418	**HYD**	Hydraulic Power Generation and Distribution			■	■		
		4. AIRCRAFT AVIONICS SYSTEMS AND EQUIPMENT - Cabin Systems						
419	**PAX**	Passenger and Freight Systems			■		■	■
420	**ECS**	Environmental Control System						
421	**WWS**	Water and Waste Systems			■			
		4. AIRCRAFT AVIONICS SYSTEMS AND EQUIPMENT - Other Systems						
422	**FUS**	Fuel Systems	■		■			
423	**LGB**	Landing Gear and Braking Systems				■		
424	**FPS**	Fire Protection Systems						

5. FLIGHT MECHANICS - Stability and Control								
501	**ANL**	Analytical			■	■	■	
502	**EXL**	Experimental			■		■	
503	**FCS**	Flight Control System			■		■	
504	**ENV**	Environmental Hazards					■	
5. FLIGHT MECHANICS - Performance								
505	**ANY**	Analytical				■		
506	**EXT**	Experimental						
6. INTEGRATED DESIGN AND VALIDATION (methods and tools) - General								
601	**ITC**	Methods and IT tools for Collaborative Product and Process Engineering						
602	**OSE**	On-board Systems Engineering					■	
603	**EMC**	Environmental and EM Compliance Engineering Process	■		■			
604	**FGT**	Flight/ Ground Tests						
605	**LCI**	Life-cycle Integration						
606	**CRT**	System Certification	■	■		■	■	
607	**FTS**	Fault Tolerant Systems				■	■	
608	**HAZ**	Hazard Analysis	■		■	■	■	
609	**SAM**	Safety modelling		■	■	■	■	■
610	**ASD**	Air Safety Data Analysis			■			
611	**REL**	System Reliability	■	■	■	■	■	
612	**SYA**	Security / Risk Analysis	■	■	■	■	■	■
6. INTEGRATED DESIGN AND VALIDATION (methods and tools) - AERONAUTICAL IT								
613	**ASE**	Aeronautical Software Engineering			■			
614	**AIP**	Advanced Information Processing		■	■			
615	**CDM**	Collaborative Decision Making			■			
616	**SEV**	Simulator Environments and Virtual reality		■	■			■
617	**DSS**	Decision Support Systems			■			

618	**IKM**	Information management and Knowledge Management (methods and tools)			■			
619	**AOP**	Autonomous Operation		■	■			
6. INTEGRATED DESIGN AND VALIDATION (methods and tools) - OPERATIONAL RESEARCH								
620	**ORM**	Development of Operational Research Methods and tools						■
621	**DSV**	Development of Synthetic Environment and Virtual reality tools	■	■	■	■	■	■
622	**ACP**	AirCraft Performance Assessment	■		■	■		
623	**APA**	Airport Performance Assessment				■		■
624	**BSM**	Business Modelling			■	■	■	■
6. INTEGRATED DESIGN AND VALIDATION (methods and tools) - R&D INFRASTRUCTURE								
625	**NUM**	Numerical Models (including fast time simulation)	■	■	■			
626	**RTS**	Real Time Simulators	■	■		■	■	
627	**GPE**	General Purpose Equipment						
628	**REF**	Reference Data for R&D Use and Live/RT Data Use						
6. INTEGRATED DESIGN AND VALIDATION (methods and tools) - VALIDATION								
629	**MTH**	Methodology						■
630	**LSX**	Large Scale Validation Experiments				■	■	
631	**LSP**	Large Scale Validation Platforms						
7. AIR TRAFFIC MANAGEMENT (Source ARDEP)								
701	**OVA**	Overall ATM		■			■	
702	**AMG**	Airspace Management		■	■		■	
703	**FCM**	Flow and Capacity Management		■	■	■	■	
704	**VAL**	Validation						
705	**COS**	Communication System					■	
706	**NAS**	Navigation Systems					■	
707	**SUS**	Surveillance Systems		■	■		■	
707	**-**	-						
709	**AVN**	Avionics		■	■		■	

710	**APT**	Airport Traffic Management		■			■	
711	**APO**	Airport Operations		■	■	■	■	■
712	**ALO**	Airline Operations		■				
713	**MET**	Meteorological		■				
714	**RDM**	R&D Management and Coordination						
715	**MMO**	Maintenance Modelling						
8. AIRPORTS								
801	**SEQ**	Security Equipment						■
802	**CMG**	Crisis Management						■
803	**AES**	Airport External Safety				■	■	■
804	**ARS**	Airport Security						■
805	**LOG**	Airport Logistic Systems						■
806	**DES**	Airport Design Features						■
9. HUMAN FACTORS								
901	**HFI**	Human Factors Integration, Man-machine Interface		■			■	■
902	**HIP**	Human Information Processing					■	■
903	**HPM**	Human Performance Modelling and Enhancement		■			■	■
904	**SEL**	Selection and Training					■	
905	**HSP**	Human Survivability, Protection and Stress Effects			■	■	■	
906	**HES**	Human Element in Security			■			■
10. INNOVATIVE CONCEPTS AND SCENARIOS								
1001	**SCE**	Scenario Analysis	■	■	■	■	■	■
1002	**UCC**	Unconventional Configurations and New Aircraft Concepts	■		■	■	■	■
1003	**BTT**	Breakthrough Technologies	■		■	■		■

A great deal of additional information on the European Union is available on the Internet.
It can be accessed through the Europa server (http://europa.eu).

Cataloguing data can be found at the end of this publication.

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The initiative aimed at identifying innovative, discontinuous, revolutionary and radical concepts and technologies for air transport of the future.

The Out of the Box project had two phases. In phase one, creative ideas and concepts were identified. In phase 2, these ideas were assessed based on their feasibility in terms of customer acceptance, economics, efficiency and technologies.

A limited number of ideas were identified as having the best potential to achieve radical changes. The topics include novel sustainable propulsion concepts and the use of ground power to increase the efficiency of flying, autonomous guidance and control for air vehicles, personal air transport systems, novel ways to connect people with aircraft and the concept of the airborne cruiser and its feeder aircraft.

The Out of the Box initiative enables a more structured approach for thinking about radical changes in Air Transport on a European level.

It also provides a mechanism for other transport modes to gather ideas about the longer term future and to promote radical changes in those sectors.

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