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INTERNATIONAL FEDERATION OF AIR TRAFFIC CONTROLLERS' ASSOCIATIONS

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ATM

A STATEMENT ON THE FUTURE OF GLOBAL AIR TRAFFIC MANAGEMENT BY IFATCA

Version 1.0 – February 2007

MANUAL

IFATCA is the recognised international organisation representing air traffic controller associations. It is a non-political, not-for-profit, professional body that has been representing air traffic controllers for more than 50 years, and has more than 50,000 members in over 120 countries.

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VERSIONS

This document will be progressively updated and improved, including developments in Air Traffic Management and IFATCA's policy.

The initial version was prepared by Andrew Beadle, IFATCA's representative to ICAO's ATM Requirements and Performance Panel (ATMRPP).

EDITORIAL

When reading the various articles in the many aviation journals, one is often amazed at the diversity of automated solutions for the perceived problems in global air traffic management. Much of this information is based on good scientific logic and reason backed in some cases by empirical data. Others appear to be the extreme of where automation could end up "no controllers – no pilots".

What will be certain is that automation is here for some and on its way for others. Among aviation professionals, including operational controllers, the idea of what constitutes automation and what it will mean to them will differ from individual, from unit, from country and from region. It will also be viewed in terms of the level of automation anticipated.

When one visits Air Traffic Control (ATC) units particularly Area Control Centres (ACCs), you will see very differing ways of solving the same problem. One common element is that either directly from the basic paper strip layout or indirectly through automated support systems, the human controller has the final arbitration on how that data will be used.

Driven by customer needs and safety improvements, Air Navigation Service Providers are turning towards technological solutions of the capacity versus demand problem. The biggest change though is that for once the ground infrastructure has the capability and desire to meet the cockpit in terms of automation. For too long the ability of the aircraft has been suppressed due to the inability of the ground-based systems and their interoperability. But as we move into a new era this is about to change, radically. However controllers are very sceptical about any change – the simple reason being that history shows that what has been promised as a positive change that will make their task easier has often, despite intensive human factor developments, resulted in another layer of problem-solving for the controller to enable the system to provide the required output. Sometimes these actions are the result of safety case mitigations, where additional procedures or reinforcement of procedures are applied to ensure safety and system operability. Often there are changes applied post-implementation as controllers discover inadequacies or failings not previously considered and what was the "work-around" to overcome these, becomes normal operations – not necessarily as designed.

But it is not all doom and gloom, as there are many new automated systems that work well and assist the controller without him or her realising that an automated system is in use. What we find with these systems is that they are taking a stepped approach to evolution rather than "a big bang" approach. Good automation will exploit the strengths of the human by using the appropriate function between human and system – examining and delivering procedures for recovery from emergencies, so that the controller knows that all is not lost should the automated function fail.

Irrespective of where controllers are in the ATC global community, there is an automated solution to a problem that we will have. It is important that controllers do not focus on the negative, but begin to look "outside the box" and embrace the inevitable change.

Service-providers are now realising that to get the best out of any new system development, it has to be developed with current operational controllers. Within IFATCA, "operational controllers" are working hard to ensure that the operational voice is heard from the highest level in ICAO – the Air Navigation Commission – through regional planning and implementation groups into regional activities.

IFATCA's "expert" opinion is now sought in research and development (R&D) being conducted by the FAA and EUROCONTROL on integration of airborne systems, FMS, PRNAV capability and communications. Airborne Separation Assistance Systems, data link and all its dimensions, four dimensional integrated solutions where aircraft and ground systems will communicate with each other through automated systems delivering solutions to problems that controllers could accept or reject, or maybe delegate to the system to resolve. This function allocation – i.e. automation and human allocation of functions is currently at the boundary – or crossroads of where we are at, and projects like ERASMUS seek to move across the crossroads in different directions. It is an exciting time, because controllers are at new thresholds of ways of doing our jobs and we are in some ways only bounded by pure imagination. The important point is that we must build integrated, holistic systems and not those that are piecemeal. This is an important key to success for the future.

But it is not all R&D and theory. In many areas of the world but particularly in the Pacific area, we are seeing the development and deployment of Automatic Dependent Surveillance (ADS) in particular ADS Contract and Broadcast, being part of the new surveillance concepts utilizing datalink.

It is all very well to enhance the Enroute sector as that has been where most of the delays have been generated, but now attention is being given to the airfield, as runway capacity will be the constraint on aviation development in the coming years.

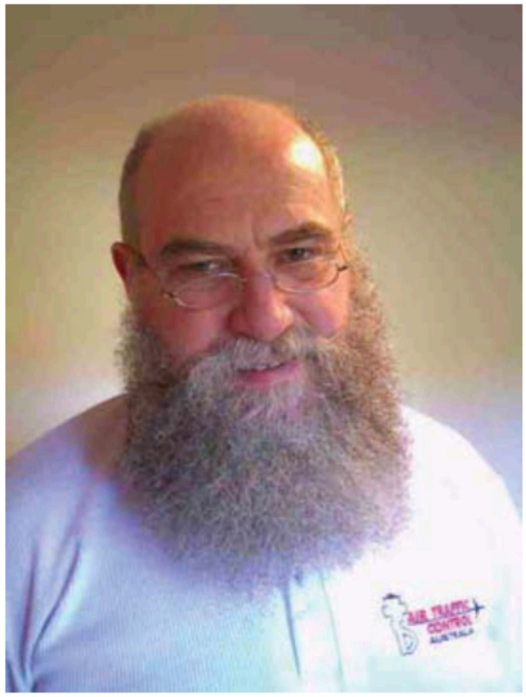
As well as capacity constraints i.e. available concrete to land aircraft, environmental issues, noise and pollution play a very large part in any new development to enhance airport throughput. Taking some of the technologies from Enroute operations and the aircrafts enhanced navigation capabilities controllers are also seeing the trial and implementation at the busiest airports of new ways to maximize the limited "runway" resource. Continuous descent approaches, use of closely spaced runways, new departure and arrival routes utilizing technology through departure and arrival managers and based on navigation containment through 4 D trajectories will all maximize the benefits gained in the Enroute stage enabling gate to gate management of flights. The development of new control towers are enabling structures to be built which have the ability to include modern daylight viewing screens and support technologies such as multilateration; advanced surface movement guidance control systems and use of datalink all assisting the controller to manage the traffic in all weather conditions. With the addition of collaborative decision management the airlines can play an active part in ensuring improved gate management and throughput of passengers from their arrival at the check in through to departure at the gate.

What I find exciting is that these introductions are coming on stream at a rate never seen before and will be as big a step to the controllers as the introduction of the glass cockpit and the jet engine was for the pilot. For once ATC will be at the cutting edge of technology instead of working with systems which were deployed 30 years ago. These enablers for integration of ground and air components so that data fusion can exist and that collaborative decision making can be used to the benefit of all will for the first time, have the potential to make full use of the onboard technology of the aircraft to enhance safety, environmental concerns and to make use of the available capacity efficiently. As controllers irrespective of the level of automation to be introduced, want to be part of the development so that controllers as customers of the new automated systems and support tools, can have an opportunity to shape and influence the way in which these will be integrated into the current systems or as part of a new concept of operations. This would be for the first time a realistic human-centered approach involving all the key components of the aviation industry.

Dave Grace, Executive Vice-President Technical IFATCA

Biography Joined ATC in 1969, President UK Guild of Air Traffic Control Officers 1989-94, Chairman of IFATCA Standing Committee - Technical and Operations 1992-2002, Executive Vice President Technical 2006-07, Currently operational Supervisor at the Scottish and Oceanic Area Control Centre Prestwick.

ABOUT THE AUTHOR



The initial version of this statement was prepared by Andrew Beadle.

Andrew is currently IFATCA's representative to the ICAO Air Traffic Management Requirements and Performance Panel. He was also a member of ATMRPP's predecessor, the Air Traffic Management Operational Concept Panel (ATMCP), which drafted ICAO "Global Air Traffic Management Operational Concept", now published as ICAO Doc 9854.

Andrew was employed as an Air Traffic Controller from 1978 until 2006 and spent most of this career as an operational air traffic controller. On commencement of his career, communication with the adjacent ATC unit was still High Frequency Single Side Band and communication to some aircraft in continental airspace still required relays via a trunk telephone system, paper strips were used, as were wax pencils on World Aeronautical Charts to plot aircraft positions. On conclusion of his career he was using an integrated display system that had no paper strips and had an integrated surveillance display for flight plan, radar, Automatic Dependent Surveillance – Contract (ADS-C) and was being prepared for ADS – Broadcast (on a continental scale). During the transits from system to system, he was frequently involved as a trainer or as project staff - especially as a technical representative of the users. He worked in Tower, Terminal and Enroute areas (including continental and oceanic, procedural and radar) and Operational Control (which was a uniquely Australian application by a service provider as this function is usually the sole responsibility of the Airline Operating Company or Pilot). He has worked with no radar, raw radar, synthetic radar and multi-tracking radar. The range of systems that he has used and been involved in implementing has assisted him in having a strong understanding of the different types of air traffic management currently deployed around the world and to be aware of trends in air traffic management.

Andrew also has written computer software for ATM. For example, he wrote a flight progress strip printing system that took information directly from the Aeronautical Fixed Telecommunications Network (AFTN) and was deployed across Australia for several years until paper strips were decommissioned in all terminal and enroute environments.

Andrew served as IFATCA Executive Vice President (Technical) from 1999 to 2006. This enabled many opportunities for sharing with controllers around the world and for seeing the systems that are deployed and planned. It enabled interaction also with pilots, senior managers of airlines and air traffic service providers, engineers and other aviation professionals and with international organizations.

COOPERATING TO CREATE THE FUTURE

Creating the Future

"The future is not some place we are going, but one we are creating." - John Schaar

The purpose of this document is to assist an understanding of where current Air Traffic Management (ATM) is, to provide a tool for gathering support of a particular approach and provide another step towards working together to create the future global Air Traffic Management that is needed.

This document is arranged so that most of the explanation and examples are contained in the appendices so that the main body of the document contains the most important points.

The Solution for ATM

The proposed solution to addressing the safety, environment, capacity, flexibility and efficiency needs of the future ATM is:

1. The Airspace User shall plan their preferred 4-D trajectory, and,
2. The ATM system will modify that trajectory to the minimum extent possible.

The difficulty with the proposed solution is that most of the states and service providers consider this is what they have always done, and are still doing today!

There is nothing wrong with the proposed solution or the position of the states and service providers – except that they are incomplete statements. The International Civil Aviation Organisation (ICAO) has published a "Global ATM Operational Concept" (Doc 9854) which supports the proposed solution but puts these statements in context. The states have accepted this approach. (For more details see Appendix 1 – ICAO Concept).

More than anything else, a comprehensive solution requires a high level of co-operation between all members of the ATM Community.

Note: To address the transport of passengers and freight a multi-modal transport solution is needed. Air transport does not exist in a vacuum, and a solution, particularly for short distance high-density operations, may be high-speed surface transport. High speed surface transport may also be used to link existing aerodrome infrastructure within the destination area so that the overall capacity of all aerodromes is used. Multi-modal solutions should especially be considered when existing infrastructure is at its capacity and major new ATM infrastructure is proposed.

Co-operation

The ICAO Concept frequently mentions "Collaborative Decision Making". This is not a "consultative" or "information" process but an involvement in the process and the consequences.

The co-operation required is a serious working together that requires pragmatism and compromise by all involved.

Pragmatism requires that issues are discussed frankly, and that no issues are left as too difficult. It especially requires that issues such as finance and politics are not left out of the discussion, because practical solutions involve both of these. Pragmatism also requires a reasonableness that does not demand more of others than you are willing to offer yourself. (See also Appendix 6 – Pragmatic Airline Expectations.)

Regarding compromise, philanthropy may occur – but what is expected is an "enlightened self- interest" that recognises that the best means to achieve the required results for self is by participating. For "enlightened self-interest" to continue to work, everyone must get something from the system that they want – and everyone must be prepared to give up something. In other words, what is needed is a willingness to concede something to get an overall better result.

It is important that there is not any attitude of "blame" for past actions, for it will not change where ATM is. There must however be a willingness from each member of the ATM community from now on to be responsible for their actions in creating the future ATM system.

In order to co-operate, it is of course a requirement to be able to communicate. The need for an evolving "Language of ATM" is addressed in Appendix 4.

The purpose of working together is to achieve an agreed goal.

Agreed goals should be expressed in three major formats; a shared vision, a shared concept and a shared performance plan.

The formats can be defined as global, regional or state. It is expected that the most common form should be regional documents that are consistent with ICAO's global documents.

Note: The periods of time used in the following sections are indicative only and the actual period should be collaboratively agreed. The period of 10 years for vision and concept iterations seems to be quicker than past experience of global ATM developments, and in the future may be even quicker.

Agreed Shared Vision – plus 25 years

All members of the ATM Community should work together to have a shared vision of 25 years in the future. It should be completely updated every 10 years.

The purpose of the vision statement is to agree and state the long-term objectives to permit research and development into possible ways of meeting that vision. It is to provide the next step after the target date for the current concept of operation.

The vision statement should be expressed in terms of functionality – and never in terms of an existing technology, an existing protocol or an existing program; otherwise it will restrict understanding and potential options for meeting that vision.

The vision statement does not have to be long and involved, though it can be. (See also Appendix 10 – No Directed Frequency Changes.)

Agreed Shared Concept of Operation – plus 15 years

All members of the ATM Community should work together to have a shared concept of operation for the overall ATM system of 15 years in the future. It should be completely updated every 10 years.

The purpose of the concept of operation is to describe all the ATM system functions required for a complete ATM system. The concept of operations provides the details of the vision statement that has been published for 10 years and so has had time to mature (including evaluation of potential options).

Although expressed mainly as functionalities, protocols can be mentioned (preferably as examples). “Named” technology or programs should be avoided. For example, “radar” has become so entrenched as a method and term of air traffic control that it has become difficult to consider what is really required for surveillance and the associated separation methods. Another example is Automatic Dependent Surveillance – Broadcast (ADS-B) which should be viewed as an example of a protocol rather than viewed as the only way to achieve functionality in a concept of operations.

The concept of operation should be expressed in some detail, but never to the point of preventing the achievement of the required functionality by other methods and technologies.

Agreed Shared Performance Plans – 5 yearly

All members of the ATM Community should work together to have shared performance plans. There should always be a plan. The period for these plans will be determined by need, but for example may initially cover the changes to ATM for the next 5 years and be amended as required.

The purpose of the performance plan is to record the outcome of collaborative decision making as to the best way from the current system towards the agreed concept of operation and vision. It records the commitment of each of the members of the ATM community.

The performance plans must describe current systems, as well as what components will be used to progress towards the Concept of Operation and Vision. The ICAO Concept uses the term "system-wide safety and business cases". In subsequent work, this is now being replaced by the term "performance case". The performance cases must evaluate the options and find the best means to address identified ATM performance gaps (in any part of the ATM system). All members of the ATM community require their involvement to be economically viable and so the cost of change must always be included. The individual plans of each member of the ATM community is not part of the shared performance plans as the shared performance plans only record joint activities for the improvement of the ATM system.

Shared Performance Plans can be amended by agreement to seize opportunities and accommodate unexpected developments. The ATM system is influenced by factors outside the control of the ATM community (for example viral disease outbreak) and so must be able to respond to such unpredictable events to minimize the negative effects on members of the ATM community. In a similar way, the ATM system should be able to respond to opportunities that benefit the ATM community.

Achieving Predictability in ATM

Cooperation occurs in the operational areas not just by the sharing of information, but in actions that ensure predictability of performance – and this applies both to airspace users and service providers.

There will continue to be elements beyond the control of the ATM system. One example is weather. Thunderstorms can be forecast but the exact position and nature of the thunderstorm will not be known with much notice – and there is no expectation that there will be a change to aircraft design or operation so that passenger aircraft will be able to fly directly through severe thunderstorms. Thunderstorms will continue to disrupt traffic flows. The ATM system design should provide means to however mitigate the consequences of such uncontrollable events as much as possible.

There are however other variables that are within the ability of the airspace user or service provider to control. It is expected that in a spirit of cooperation for overall system benefit that reasonable steps will be taken by the airspace users and service providers to control the variables, so that the ATM system is more predictable. See Appendix 11 for "On Time Performance".

Cooperation in the operational area also includes sharing of tasks, such as separation provision.

Constant Incremental Improvements

Improvements to ATM can be made by improved system design, procedures and technology. Indeed, much can be accomplished with current technology.

It is unlikely that new technology, procedures or system design will have a large single-step improvement to ATM. One factor is that the existing aircraft fleet will continue in operation for many years and it would be expensive to retro-fit these aircraft. Even if retro-fitting was agreed, it would take time (several years) to economically update a fleet of aircraft.

ATM improvement s should be seen a series of incremental improvements towards the shared concept of operation and vision.

In order to make changes to ATM easier to manage, past changes to ATM have often been viewed on an "exclusive use" (or segregation) model - in other words, access to airspace based on equipage and no mixed-mode operations. This is a regulation approach to managing the situation. However often events, such as operation of military aircraft, has meant that there have been significant mixed-mode operations in airspace not designed for it. Such ad-hoc operations do not contribute to a safe system.

Future ATM systems should be designed on the basis that constant incremental improvements will be made, and so the ATM system should be designed for mixed mode operations. This will eventually be a safer and more robust system, but considerable work is required in the design and operation of a mixed mode system. For example, the system may be designed to accommodate only a certain amount of mixed-mode operations which then requires monitoring of the level of mixed-mode operations and procedures that ensure that the level is never exceeded.

However once established, mixed mode ATM will permit aircraft to use improved systems immediately (and not at some future "implementation date"). Also, a new ATM service may be provided that, for a fee, assists an aircraft meet a particular performance requirement to use a particular ATM functionality. This example would enable the airspace user to choose whether to retro-fit an aging aircraft or whether it is more cost effective to use the service offered by the ATM service provider until the aircraft is retired from service.

The ground systems of ATM can evolve at a much higher rate than airborne systems. (For more information see Appendix 7 – "Evolving Ground Systems"). Ground systems have lagged behind airborne systems but can now rapidly catch-up and offer significant improvements to ATM services.

PERFORMANCE EXPECTATIONS

The future ATM system must be performance based. Performance will be assessed for the whole ATM system, which is for all members of the ATM community.

ICAO has developed "Performance Based Transition Guidelines" and is producing an "ATM Performance Manual". See Appendix 1 – ICAO Concept and Appendix 13 – Performance Based ATM.

The ICAO Concept requires that the future ATM system be driven to meet the expectations of the ATM community and be performance based. The ICAO Performance Based Transition Guidelines discusses identifying and correcting performance gaps.

It is important to use performance measures to achieve a goal – and not focus on the number (performance measure) as if it were the goal.

The expectations in this alphabetical listing are to be addressed simultaneously; however note that (as the ICAO Concepts states) "the attainment of a safe system is the highest priority in air traffic management".

Each expectation will now be listed with a comment about some performance gaps that should be addressed in future ATM systems.

Access and Equity

The current approach to access to controlled airspace is drawn from the regulator background – we will let you in when it is safe to do. The future ATM service-based industry approach is that "we want your business and will get you into the airspace if we can" (and of course do it safely). Both approaches may work in a similar way to a similar safety level – however the first tends towards demanding that the airspace user do what is necessary to enter safely and the second approach tends towards the service provider making every effort to make it as easy as possible for the airspace user to have access.

Capacity

Available ATM Capacity will no longer be managed as "number of aircraft per sector" but in the "number of tactical interventions required" as strategic conflict management establishes orderly flows of air traffic.

The service providers' understanding of "sectors" and "centres" airspace will evolve and no longer be strictly geographically fixed, enable sharing of workload both within service providers and between service providers to provide maximum system capacity and respond to disruptions.

Cost-Effectiveness

This is cost-effectiveness of the entire ATM system. Changes to ATM are needed and will have to be funded. In a cooperative approach, those who benefit financially from the changes should pay for the change and where there is no financial benefit no charge. Likewise it can be argued that if a change is imposed on ATM by the state (without benefit to ATM but meeting a wider community need) that it should be state funded (however this does not often occur).

Efficiency

This efficiency relates to a single flight perspective of efficiency. It is expected that future ATM will be able to provide services based on an individual flights requirements (for example, using user supplied 4-d trajectory). What currently is missing is a feedback to (or monitoring by) the service provider of how successfully they met the airspace user's need for a particular flight, prompt corrective behaviour to negative trends and reinforcement of positive trends.

Environment

This relates to gaseous emissions, noise, visual intrusion, etc. Each member of the ATM community is individually responsible for behaving in an environmentally responsible manner. It could therefore be argued that if the airspace user flies their requested 4-d trajectory without modification that they would therefore be responsible for all environmental consequences of that flight – however this is too simplistic as the combination of all ATM activities is a community activity and there will be a level of shared commitment, collaboratively agreed, to the ATM system operating in an environmentally sustainable way.

Flexibility

A major limitation today is the inability of service providers' systems to share trajectory information in a timely manner (even basic flight plan information). Often this is between service providers' "centres" but also occurs within centres. Therefore the first step towards future ATM 4- d trajectory management is the timely sharing of ground data, especially between any adjacent positions (whether in the same room or not).

Another major limitation is the service providers' lack of surveillance or even electronic displays in many parts of the world that severely limit the service providers' ability to assess, coordinate and approve requested changes.

Global Interoperability

Interoperability is not necessarily a "single (technology) system", but instead a standardisation at a function level. Standardised functionality will allow implementation of evolving technology, and can be more "cost-effective" than mandating a single technology.

What is needed is a definition of the functions required to enable global interoperability. See also Appendix 12 “Black Box Interoperability”.

Participation by the ATM Community

Participation needs to a real involvement in the entire process and consequences. Some participation has started, but much work is still required in establishing appropriate structures and procedures. Such structures should support and complement the ICAO structure (as it too evolves). The best way to fund activities relating to participation also needs to be collaboratively addressed.

Predictability

Predictability will require effort by service providers, airspace users and others to deliver agreed performance, especially over events that can be controlled (or mitigated) by that member of the ATM community. Uncontrollable events (such as weather) should not be simply accepted as disruptive, but should be prepared for with collaboratively-agreed mitigation plans, “game plan options”, etc. so that the consequences to predictability of uncontrolled events is mitigated to the maximum extent by actions of all relevant members of the ATM community acting in concert.

Safety

Safety Management has effectively become risk management. The concept of a “safety margin”, which is the safety buffer above the calculated risk, seems to have been forgotten. In a system such as ATM where not all events are controllable, safety margins (that is capability above the requirement) should exist and changes to the margin be monitored.

Another significant safety issue is “self-contained rest of flight capability” for aircraft. For example, if there is a major disruption to external information sources (such as accurate time and navigational information) the aircraft should be able to continue for the rest of flight with self- contained systems providing appropriate accuracy (for example an internal time system and a fall-back basic inertial reference system). Likewise ATM should improve procedures so that the flight can continue safely on its 4-d trajectory even if communication with all external sources is lost.

Security

ATM communications, including voice and datalink, is not encrypted or source verified (for example by electronic certificate) in any manner. It is susceptible to malicious attacks, including false information and jamming. For example it is possible to transmit false ADS-B information, or to use correct ADS-B information to track a particular aircraft.

HUMAN AND TECHNOLOGY

Humans together with Technology

The ATM system is comprised of humans and technology (acting via procedures on information).

Clearly there is a need for the technology, for without technology for flight there would be no ATM system. However, the need for humans at operational levels is under discussion. The "flight engineer" is no longer a standard member of the flight crew. Unmanned Aerial Vehicles (UAVs) are rapidly increasing in number and sophistication. Are air traffic controllers becoming redundant?

Humans will be necessary in the operational areas, including air traffic controllers, for many years – but as the technology and system evolves, the role of humans will evolve.

The need for humans is because of the strength of the human in managing systems in a rational and flexible way (that is based on sensible thinking and judgement not programming), especially including handling unforeseen events.

The problem has been "that is err is human" and many ATM system "errors" have been assigned to human error. This has led to the belief that the human is the cause of the problem and that removing the human will improve safety. However, "to act unreasonably and inflexibly" at times seems to be the attribute of technology, especially when unanticipated events are encountered. Human operators have become very frustrated at being blamed for "errors" and yet receive no recognition that it is in fact humans who have made the automation work (for example by doing tasks that automation was supposed to handle but doesn't do so correctly). What is needed is recognition that the strengths of the human and the strengths of the automation are both needed – and that both have limitations that must be mitigated.

With extended development and use, technology can replace certain human activities. There has been much learned in progressive development of flight deck systems that makes UAVs feasible for some operations today. There is no such equivalent yet in the development of systems that would replace air traffic controllers – but this is not to say that future systems may replace some air traffic control functions. The "assistant" to the executive controller, whether a controller or support staff, is in the not too distant future going to find themselves compared to the flight engineer.

It is difficult to talk of technology on a "global scale" in relation to Air Traffic Management systems. In a so-called "advanced technology" industry such as air traffic control, it would be expected that electronic display systems would be the norm – if only because electronic displays support the sharing of data much more efficiently than information on paper. It is not only third world situations were such displays do not exist – but even a busy environment such as the North Atlantic is only now getting electronic air traffic control displays for the entire route! It is an indictment to air traffic management that some Airline Operating Companies can display updated aircraft positions for their fleet around the globe but the air traffic management system cannot.

However, assuming that the collaborative global approach to air traffic management will first identify and address the most pressing needs, the rest of this section will address what is the next step from basic electronic display of traffic and basic electronic sharing of ATM data.

Humans and Automation

In order to meet the increasing safety and other performance targets of ATM, an increasing level of automation will be required – however the human shall at all times remain the manager of (and not the servant of) the automation. In basic terms this means that the human will choose what is to be done, delegate the execution of the task(s) to the automation and be able to intervene if required.

The automation support of the human roles within ATM must be developed and implemented in a way that fosters trust and confidence by the human in the automation functions. Experience (both good and bad) regarding the successful implementation of automation to the cockpit will be used in designing automation in other areas of ATM, especially for air traffic controllers. High- reliability systems such as fly-by-wire, full automatic landing, etc have been implemented in aircraft and a similar rigor is required in the development of ground-based automation, especially when the automation function (or failure) will have consequences for multiple aircraft at a time.

The tasks and nature of human roles within ATM will evolve with the automation. For air traffic controllers this will involve changes such as reduction/removal of “house-keeping” tasks such as frequency changes, the delegation of specific tasks or responsibilities to other agents (both human and automation), adjustments in work-style to support a more strategic trajectory management traffic flow, changes to the staffing required at positions, etc. It is important to make sure that the job satisfaction and pride remains high and the overall human experience in the future system, while different, will not be any less attractive or important than it is today.

The humans’ role in the system will be by design, and not become a residual task such as “the human does whatever the automation can’t complete”. The ATM system design approach will ensure that the strengths of the human and of the automation are both maximized while the weakness of the human and the automation are both minimized. Degraded and Recovery modes of automation will especially ensure that the human is never overloaded or expected to do more than is humanly possible.

System error - that is not just “human error” but the deficiency of human and/or automation – will be monitored and lessons learnt. The human will not be responsible for automation that is not within the ATM system design (or capacity) of the human to monitor and manage. The human operator of automation will not be responsible for automation behaviour that is not within operator’s ability to influence. The human will not be responsible for information supplied by automation that the human is unable to verify. The human will not be solely to blame for failure to use the automation correctly if the actions of the human were not grossly negligent (as a deficiency in the automation’s interface to the human is also indicated). When the human has to change work practice as a work-around to a task that automation is supposed to do but doesn’t, then this will be treated as a system error that should be promptly corrected.

The changes in humans' role within ATM will affect staff selection, training, recency requirements (especially for "emergencies" involving degraded automation) and possibly even ratings and endorsements.

Representatives of the humans who will "operate" the automation will be involved throughout the design, simulation, implementation and review of the automation.

Technology

ATM Specific and Commercial-Off-The-Shelf

We live in a technological age in which many industries are dependent upon technology. In order to achieve cost-effective improvements, ATM should make maximum use of appropriate technology which has been developed for generic use (that is not specifically for ATM). For example, radar screens and the graphics processors that made the screens functional were once specifically developed for radar applications and available only from ATM suppliers. Now however the Information Technology (IT) industry has developed screens and graphics processors vastly superior to what was available within ATM. Further research and development, which is not specifically paid for by ATM, is improving the performance and lowering the cost of these screens and graphics processors.

One big issue has been the issue of "reliability" for ATM equipment. However much of the reliability of ATM equipment appears to be theoretical and is based on production runs measured in hundreds. Promised reliability is not always delivered. With generic IT equipment, there is the practical experience of production runs in the tens of thousands. The reliability of equipment needs careful consideration, especially when the cost of generic equipment is only a fraction of the cost of the specific ATM equipment (so that a good quantity of spares can be purchased economically). This does not mean that any generic IT equipment will do. Whether equipment is supplied from within ATM or "commercial off the shelf", the equipment will always require appropriate evaluation.

ATM should carefully define those areas where specific and unique ATM requirements demand specialist ATM technology – and ensure that on-going research and development of such technology occurs. For other technology, Commercial-Off-The-Shelf equipment may meet ATM needs.

Use of non-ATM expertise

In the specification of ATM systems it seems that expertise from areas outside ATM is ignored. For example, when discussing future ATM systems, much is made of the need for information sharing (specifically System Wide Information Management (SWIM)) and generic attributes of the data (quality assured, etc). The need for information-sharing is not unique to ATM, and so expertise from outside ATM should be used. This applies to other areas too, such as software development.

ATM should not re-invent systems where expertise is available from outside ATM.

ATM Needs

ATM does have specific needs, not only in the aircraft, which will require careful preparation and execution.

The ATM system has:

1. Components that are in continuous operation (eg service provider equipment).
2. Data needs that require updates, both planned and corrective.
3. Program upgrades, both planned and corrective.
4. Failure modes that ensure essential functionality remains.

At present, the ATM system has service provider equipment that in order to be upgraded (program or data) then the equipment will act in a "degraded mode" – for example without short- term conflict alarms. However program and data upgrades should been seen as a normal activity and the service providers' systems should be designed in such a way that there is no "degraded modes" (no reduced functionality) for normal operations (including program upgrades).

At present, many ATM systems hold only one version of data at a time, yet scheduled updates to ATM data is a normal ATM activity. Of course there are issues to be addressed if operations are being conducted at the time of scheduled update, but these problems are not impossible to overcome.

At present, the ATM system has databases (both ground and airborne) that cannot be progressively updated if errors are found or unforeseen events occur. Either the errors are corrected in the next planned update cycle, or in some cases an update may occur earlier than planned but the system still operates for a period on incorrect data. At present the mitigation is to tell the humans (publish a NOTAM) and expect the human to somehow manage the error. A system is required that allows updating incorrect or changed information as it occurs.

The recommended solution to these problems is to view the ATM system as compromising of many independent, fully capable units; with each unit being able to communicate with any other unit. For example, the aircraft would be a unit and each air traffic control console is a unit. The processing power exists both in the air and on the ground to do this using current technology. For example, the short term conflict alert could be built into the air traffic control console, so that except when the console itself fails, the alert is always active.

A secure datalink should be able to be established between any two units of the ATM system.

ATM Capability Level

There is a need to define levels of capability within the future ATM system. This will apply to both airspace users' and service providers' capabilities as the traditional disconnect between air and ground components should not be continued. The capability will indicate level of ATM functionality achieved. The ATM capability level will indicate that all components are operational – that is humans have been trained and rated, technology implemented, procedures established, etc.

Each level of ATM needs to be collaboratively agreed, preferably on a global scale.

The concept of "management by trajectory" is fundamental to future ATM. The first level of ATM Capability should define existing systems that have initial elements of management by trajectory. Each higher level will indicate higher management by trajectory capabilities and other ATM functionalities as agreed. A level of ATM 0 could apply to existing service provider systems and aircraft that do not meet a minimum management by trajectory capability, as these will need to be accommodated initially.

Note that each level of ATM capability should be described as functionalities. Specific systems or technology would be listed as examples only (for example, "high accuracy, high frequency automatic reporting of position - this functionality can be met using ADS-B out").

See also Appendix 14 – ATM Capability Level Examples.

USING ICAO GLOBAL ATM OPERATIONAL CONCEPT COMPONENTS

The ICAO Concept lists seven components and states that the ATM system cannot function without the integration of all of the components.

The purpose of this section is to provide some additional information and observations under each of the components and then comment on specific sections from the ICAO Concept.

The ATM Community

The ICAO Concept describes the ATM Community and makes many references to it. The ATM system is to be designed to meet the needs and expectations of the ATM community.

The ATM Community is like other communities. There are of course individual rights – but there are also community responsibilities. In the ICAO Concept one such responsibility is participation in the collaborative decision making which is fundamental to the success of the concept.

Airspace Organisation and Management

Airspace is owned by states (or is international airspace administered by a state under international agreements). The sovereign rights of states will not be affected. Despite international agreements which will harmonise some legal issues for ATM, there will still be state- based judicial precedent and practice which means that ATM will have to continue to deal with different legal systems (as other international business and activities do).

States are interested in airspace for security (for example, military), for protecting the interests of its citizens (for example, safety and environmental issues) and for revenue (for example, resource use fee, taxation, etc.).

In relation to military activity, there is a need for the military to be aware of the impact on civilian traffic of military activities, especially discretionary activities. Discretionary activities are activities that can be moved in location, or time of activity or both (for example training and testing). For example, it would seem difficult to justify the cost and traffic management difficulties associated with displacement of the whole North Atlantic Track system (thereby affecting many aircraft) due to airspace reserved for a few military aircraft being tested. Military operations which are not managed by trajectory have the greatest effect on ATM capacity and efficiency as usually significant blocks of airspace are made unavailable to all other operations. It is important that states reinforce to their military the importance of full cooperative participation in airspace management.

In relation to the interests of its citizens, and in particular in relation to safety, the states have a regulator. Some regulators deal with issues related to environmental protection but increasingly there are independent activities and legislation to deal with issues such as noise around airports. The concern is that some groups do not have an understanding of the safety consequences of some noise abatement procedures. For example, a runway is chosen not because of a desire to annoy or inconvenience a particular group of people, but rather due to the need for an into wind runway. Indeed, some states have published large downwind and crosswind components as acceptable for noise abatement which aircraft designers only expected to be used occasionally and definitely not repetitively. Noise is not the only issue, but issues such as visual intrusion also need to be addressed. In future ATM it would seem desirable that issues relating to environment should be coordinated via the regulator (who should have the expertise to recognise safe operations). Note: In the collaborative decision-making environment of the ICAO Concept many groups will be involved, and ATM will address environmental concerns of one of the expectations of the ATM Community.

In the ICAO Concept, “all airspace will be the concern of ATM and will be a usable resource” and all airspace is managed. So, both “separation service airspace” (today’s controlled airspace) and “non separation service airspace” (today’s uncontrolled airspace) is managed airspace. Admittedly the degree of management varies, but the principle is that no airspace is excluded from being a useable resource.

In the ICAO Concept, “airspace management will be dynamic and flexible”. How dynamic is yet to be determined by the ATM community; however, it will be determined in two ways. First the ATM Community (or regulator) will determine that a particular service is required for safety (for example, separation provision service) or, as part of ATM system design the ATM community will decide that a service is required for efficiency. It is expected that rules will be collaboratively agreed regarding the establishment/disestablishment of services. In meeting the requirement to be dynamic and cost-effective, it is possible that a service will not be provided continuously, but instead as needed. This may mean closure of control towers during low density operations (such as at night), and even the reduction of “separation provision service” (controlled) airspace during off peak times. Likewise, when needed, separation provision service airspace could expand in response to weather diversions, etc. Of course, this is not an ad-hoc arrangement, but something that is part of the ATM system design.

In the ICAO Concept, “any restriction on any particular volume of airspace will be considered transitory”. The ICAO Concept also states, “Although there will generally be no permanent/fixed constrained airspace, certain airspace will be subjected to service limitations, including access over an extended period, motivated by national interests or safety issues and appropriately considered in coordination with the ATM community.” One way of implementing this concept is for a regular review by the ATM community of all restrictions based on airspace volumes (including military operations), with a view to minimize the volumes and times of the airspace restrictions and wherever possible to manage flights using trajectories (not airspace segregation). This then allows for certain areas to be “restricted” but ensures that the need for such restrictions is understood by the ATM community.

In the ICAO Concept, “airspace boundaries will be adjusted to particular traffic flows and should not be constrained by national or facility boundaries”. For this to work a number of items need to be addressed. Real time sharing of trajectory information between adjacent controller positions is essential. However, a major issue yet to be addressed is service provider charges (and or state revenue). An airspace user’s trajectory should not be chosen based on the cost of service provider charges, as this would be an artificial imposition on the use of the ATM resource. This however does not mean that the user pays whatever charge is levied. Initially as there is only a single service provider for a given airspace a charging system could be that the user pays a “network access fee” and it is up to the service providers to divide up that fee among them. In the longer term, if there are multiple service providers in a given volume of airspace then the airspace user would pay the fee of their chosen service provider.

The separation provision service providers will need to have arrangements established for managing using traffic flows. The facilities’ boundaries may not be fixed and may adjust to the traffic flows. This also would affect the sector boundaries within each facility. This will initially not be totally dynamic, but somewhat like the oceanic flex track system, in which optimal tracks are published for a period of time, the facility boundaries may be determined on a periodic basis using forecast conditions, including filed trajectories. Automation support will be needed as well as training service providers staff in these new procedures.

There may continue to be a need for fixed routes – when required overall ATM efficiency (for example to strategically de-conflict high density traffic). There are several issues that must however be addressed. The number of fixed routes must be kept to a minimum, including minimum length and minimum period of application. The routes will be as direct as possible. The routes will be regularly and collaboratively reviewed, including assessing whether they are still needed.

There will not be only “one type of airspace” (even though it is all managed airspace). Different levels of services, rules of conduct, etc will be determined as part of the collaborative ATM system design process.

Aerodrome Operations

Cooperation is essential for efficient aerodrome operations. Aerodrome Owners have to supply the needed ground infrastructure and need to be convinced of the value in making changes to existing infrastructure (like other members of the ATM community do). Airspace Users are operating at the most critical stages of their flight (landing and take-off), have to interface with a number of services (both airside and landside) and usually have the most factors influencing the predictability of their own operations. ATM Service Providers are providing separation services with aircraft and other vehicles operating in very close proximity to each other and where uncontrollable events (such as change in wind direction) can require complete changes to the traffic pattern in the air and on the ground. Environmental issues, such as noise and visual intrusion, affect operational choices. Airport capacity has been identified as a limiting factor to growth of air transport.

The “enroute to enroute” view of aerodrome operations means that service providers will act in concert to assist the airspace user in achieving an efficient turn-around time.

“Enroute to enroute” also indicates the aerodromes involvement with the services offered in the airspace surrounding the airport - not just final or initial stages (that is in the terminal area) but “from cruising level to cruising level”. Traditional service boundaries of “airport”, “terminal” and “enroute” should have no operational consequence on the user’s trajectory. This is not to say that different needs must be addressed as the flight progresses, for this is a practical reality, but instead states that how the services are organized to meet these needs should not affect trajectory.

The 4-d trajectory will include all movement of the aircraft (for example, from parking to gate) and will not just be limited to the taxiways and runways. The 4-d trajectory contains time elements, which may be precise requirements when needed to meet capacity demanded.

In the ICAO Concept, "runway occupancy time will be reduced". This can be in several ways, including brake-to-vacate procedures. The 4-d trajectory may in future nominate entry and exit points for the runway other than full-length when necessary to meet capacity demanded. In addition to high-speed exit taxiways, there may be high-speed entry taxiways. As it becomes difficult to create new airports in some environments, closely spaced runway operations and runways for specific type of operations (for example very light jet) may develop. Departing at a precise time is likely to be part of the 4-d trajectory; however, the finalization of the exact time may occur close to the departure time. Also, in the ICAO Concept, "flight parameters will be available to the ATM system, allowing for dynamic spacing and sequencing of departing aircraft, thereby minimizing wake vortex constraints on runway capacity".

In the ICAO Concept, "the capability will exist to safely manoeuvre in all weather conditions while maintaining capacity". The capacity requirement can be partly but not completely achieved and therefore should be qualified (and also kept as a goal). If the weather issue is only one of low- visibility only (for example, fog) then the future ATM system should be able to continue operations while maintaining the same capacity as when there is no fog (due to improved technology). However, if the weather is severe thunderstorms over the aerodrome (preventing safe flight) or obstruction of the runway (due to extremely heavy rain or snow) then clearly capacity cannot be maintained.

In the ICAO Concept, "precise surface guidance to and from a runway will be required in all conditions". This is a long outstanding need, especially to meet the preceding requirement. The 4d trajectory applies during taxi, both from and to the runway. Elements such as "virtual stop bars" may be included in the trajectory to assist in the prevention of runway incursions.

In the ICAO Concept, "the position (to an appropriate level of accuracy) and intent of all vehicles and aircraft operating on the movement area will be known and available to the appropriate ATM community members". This information sharing should enable the service provider to instruct an aircraft to follow another even in low visibility. It may also provide information to aircraft about to land or take off if the runway is occupied. How best to display this information, especially in the aircraft, requires further work.

Demand and Capacity Balancing

Another way to state the meaning of the ICAO Concept is "Capacity Management first, then Demand Management" – but this again comes down to misunderstandings as service providers claim this is what they have always done. Similar misunderstanding are evident with statements about "ATC delays" by airspace users when the controllers actually delivered more through put than the sector capacity was rated at, despite weather and technical difficulties.

Airspace capacity is not linked to the number of aircraft in a controller's sector, but the number of interventions (and other work) of the separator (pilot or controller). (See also Appendix 9 – Flexibility and Capacity.) The number of interventions required is directly related to the separation methods available, and especially the size of the separation standard – which often depends on the technology available.

Despite claims that self-separation will reduce separation standards, this has yet to be confirmed (as air to air separation standards have not been defined). Automation support will be required to assess airspace capacity, especially in high density user preferred 4d trajectory environments.

A major effect on Airspace Capacity is thunderstorms. Thunderstorms are expected events and are forecast with some accuracy – however the exact location and intensity of the thunderstorm is only known in close to real time. The activity of the thunderstorm rapidly varies so the path for one aircraft around the thunderstorm is not necessarily suitable for an immediately following aircraft. There are examples of aircraft proceeding under their own navigation in areas of extreme turbulence – and of other aircraft avoiding the area in excessive amounts that affect the flow of traffic behind them. Significant effort should be made to determine a safe and efficient means of transit or avoidance of areas of high convective turbulence in a consistent manner.

Aerodrome capacity is perhaps easier to estimate than airspace capacity, and it will be a significant improvement to ATM capacity that (at locations where it is needed) low visibility operations do not reduce aerodrome capacity.

If it is assumed that improvements to separation methods and standards mean that airspace capacity is not the major limiting factor, then the main constraint is airport capacity.

The earliest airspace user's need (in relation to Demand and Capacity Balancing (DCB)), is for airlines to be able to publish a schedule with the expectation of slots being available at both departure and destination (for one is no good without the other). These slots allocations cannot be independent of ATM but integrated into the ATM resource management.

The nature of aerodromes is evolving in a similar way as for Air Traffic Service Providers. Aerodromes are increasingly no longer "government supplied infrastructure", but businesses. It could be argued that if an airline has a high need for infrastructure at a particular location for their operations then perhaps, they should act for runway capacity as they do now for gates, that is a lease agreement with the airport owner for certain capacity or right. However, the business arrangements evolve, ATM will need to know what capacity is going to be used (really used not just "planned") and what spare capacity exists to accommodate shorter-term needs such additional airline flights or needs of business and general aviation.

Even if capacity far exceeds demand, whether for aerodromes or airspace, this does not prevent short-term demand exceeding capacity – for example many flights all planned to depart at exactly the same time. While commercial reasons may require the airlines to publish a common departure time as their competitor, this cannot be carried forward to the ATM system. Likewise, current systems which allow a wide time margin (say 10 minutes) on an allocated slot time are also unsuitable in managing ATM resources. There needs to be a balance between precision and flexibility, so that while precise times may be planned, is should be possible for a quick and easy modification of times, both at departure and destination, without major penalty. The rules of exchanging "slots" would be collaboratively agreed by the affected members of the ATM community. For example, the change should initially be accomplished internally to the airline company's operations (within reason).

In the current ATM system, the service provider addresses many "resource conflicts", which is when the airspace users want to use the same ATM resource at the same time. The future ATM system will resolve such resource conflicts using collaborative decision making. When short term actions are required, it is likely that the resolution will use a set of collaboratively agreed rules, rather than initiate a process of collaboration.

In Capacity Management, there should be an approach that provides a basic fixed capacity on expected need (as collaboratively agreed) and also an understanding of variable capacity that can implemented (either with some notice or very short notice). This variable capacity may involve extra cost or have consequences on availability of an ATM resource in another location (for example assistance from adjoining service providers).

Another consideration of Capacity Management is to identify key areas or issues that significantly affect capacity and take action to ensure capacity will be available. For example a service provider may (in order to ensure full capacity is available) have extra staff employed to cover short-term illness, provide extra assistance, relief, etc. to that normally rostered in order to ensure that capacity at peak times in not affected by expected (but not precisely predictable) events such as short-term notice of illness.

In the ICAO Concept, "through collaborative decision making at the strategic stage, assets will be optimized in order to maximize throughput, thus providing a basis for predictable allocation and scheduling". This process should also be used to make sure that capacity is responding to trends in demand, which is ensuring continuing changes to ATM assets (including new infrastructure) where optimization of existing assets will in future not be able to meet the trend in demand. This includes changes in the nature of the demand (for example, responding to growth of low-cost carriers to alternative aerodromes).

In the ICAO Concept, "through collaborative decision making at the pre-tactical stage, when possible, adjustments will be made to assets, resource allocations, projected trajectories, airspace organization, and allocation of entry/exit times for aerodromes and airspace volumes to mitigate any imbalance". This paragraph emphasizes the capacity management first (then demand management) approach. ATM capacity management involves having the ability to make additional (variable) capacity available to reasonably expected events (such as thunderstorms, staff unavailability, etc). In the same way as airlines cooperate in rescheduling passengers when aircraft assets become unavailable, service providers should be able to cooperate when a service provider's assets are temporarily unavailable.

In the ICAO Concept, "at the tactical stage, actions will include dynamic adjustments to the organization of airspace to balance capacity, dynamic changes to the entry/exit times for aerodromes and airspace volumes, and adjustments to the schedule by the users". Although this starts as capacity management (airspace organization), it also recognizes that demand management (changes of schedules) is also needed at times. Some events are beyond the control of any member of the ATM community and so the response must be to mitigate the consequences. Contingency agreements should be collaboratively created and agreed so that the response to such situations has at least some measure of equity, order and predictability.

Note: Although the terms strategic, pre-tactical and tactical are used, these are used to give a sequence of events (and not "traditional" meanings of these terms).

Traffic Synchronization

Traffic Synchronization is about achieving maximum capacity.

In the ICAO Concept "traffic synchronization refers to the tactical establishment and maintenance of a safe, orderly and efficient flow of air traffic". The significance of new ways of achieving this should not be underestimated.

Traffic synchronization can be used for same direction traffic and also for crossing traffic. Traffic synchronization can be used on the surface and during climb, cruise and descent.

In the current ATM system there is the question from the airspace user "what is the ATM resource limitation restricting my operation"? The answer is "the aircraft in front of you!". The reason for so much speed control (and vectoring) in the terminal area during arrival in high density operations is to ensure that the preceding aircraft does not slow too much too soon and to establish traffic synchronization to the arrival runway.

Conflict free 4-d trajectories are not the answer as unless 4-d trajectories are extremely precisely defined and flown (within a few seconds of time), capacity will be lost. An accurate time at the Final Approach Fix is not enough to ensure separation during descent.

The solution to achieving maximum capacity of airspace and aerodromes is traffic synchronization. Basically, this means that although a 4-d trajectory may be conflict-free (or is one designated as requiring some separation provision) there will be segments of the flight where the operation of one aircraft will require small adjustments to be synchronized with other traffic in order to achieve maximum capacity.

It is expected that before self-separation occurs in high density operations, that tasks such as "maintenance of spacing" will be assigned to the flight deck. Spacing is not the same as separation. Spacing needs to be in excess of the separation minima, so that failure of spacing can result in action before failure of separation. The role of separator is not delegated, and this is not a form of cooperative separation, but instead a new form of "air traffic control instruction", which requires compliance.

Traditionally spacing is expressed as distances but aircraft designers state that automation would be easier if a time is used. Whether it is distance or time, precision will be required. The spacing should not be viewed as an "aim" but instead a hard "requirement". If it is not a hard requirement then extra spacing will be needed (to deal with loss of spacing) and capacity will be lost.

In the concept, "wake vortex ...will continue to be a determinant of minimum spacing". The ICAO Concept is discussing longitudinal separation, especially arrivals and departures from the runway. Work will be required in reviewing wake vortex separation standards, especially to allow for the beneficial effects of wind and the availability of flight parameters expected in the ICAO Concept. In addition, this does not necessarily apply away from the immediate vicinity of the airport. For example, if a spacing less than wake vortex separation was desired between two arriving aircraft, the second aircraft could be instructed to maintain the smaller distance and additionally instructed to descend above the wake of the precedent aircraft (air to air exchange of first aircraft's 4-d trajectory could make this possible). Both aircraft could maximize preferred descent profiles, and still arrive in an orderly sequence.

An important issue is the degree of tolerances applied to spacing. The spacing is not a minimum displacement – but a displacement with (small) tolerances. As in-trail sequences frequently involve more than two aircraft, the second aircraft cannot use spacing as a minimum displacement as it would affect the third and remaining following aircraft.

In the ICAO Concept, "there will be dynamic four-dimensional (4-D) trajectory control and negotiated conflict-free trajectories". Spacing instructions will eventually become part of "management by trajectory", but initially it is likely that spacing instructions will be a separate instruction that complements the 4-d trajectory control (in the same way as a heading instruction does not cancel an airways clearance). Effective spacing techniques (together with management by trajectory) should reduce or eliminate traditional path stretching by radar vectors to establish a sequence.

In the ICAO Concept, "choke points will be eliminated". Traffic Synchronization is achieved by small adjustments to trajectory, and displacement can be in any of the four dimensions. For example, a small height displacement and a small time displacement could enable an aircraft to cross above (so clear of wake vortex) and behind crossing traffic. Separation standards that recognize combinations of displacements together with accurate trajectory (including intent) information should greatly reduce, if not eliminate choke points for route crossings.

In the ICAO Concept, "optimization of traffic sequencing will achieve maximization of runway throughput". For departures, spacing instructions on departure is how 4-d trajectories can be used and not compromise aerodrome capacity. For arrivals, spacing instructions will ensure all available capacity is used. In single runway operations (both departures and arrivals), spacing between arrivals will ensure departure "slots" are available when needed.

Airspace User Operations

Without the airspace user there would be no need for Air Traffic Management! This is true for two reasons. The first is the obvious reason (no user, no ATM). The second reason is perhaps the real reason for ATM – that the airspace user is not a single unified whole but many diverse types of missions and aircraft and there are conflicting demands by the airspace user for the same ATM resource (aerodrome or airspace). The ATM system is established to enable all this activity in a safe, orderly and efficient manner.

In the ICAO Concept, the military is an airspace user. All airspace is an ATM resource and the military are expected to work in collaboration with other members of the ATM community to achieve the most efficient operations for all.

In the ICAO Concept, "the accommodation of mixed capabilities and worldwide implementation needs will be addressed to enhance safety and efficiency". The ATM system will be in constant change and will be designed for mixed-mode operations; in any case the ATM system is required to accept mixed capabilities of airspace users. The world-wide implementation needs will be addressed by interoperability being described in functional terms.

In the ICAO Concept, “relevant ATM data will be fused for an airspace user’s general, tactical and strategic situational awareness and conflict management”. The design and availability of such data systems will be part of a collaborative process that determines the different requirements of different airspace users. It will be based on identified needs and should be cost-effective.

In the ICAO Concept, “relevant airspace user operational information will be made available to the ATM system”. The sharing of data is part of the collaborative approach within future ATM. In particular, airspace user operational data will assist the service provider to assist in making each flight as efficient as possible and to maximize the available capacity of the ATM system. Concerns about security of commercially sensitive data, etc. will be addressed.

In the ICAO Concept, “individual aircraft performance, flight conditions, and available ATM resources will allow dynamically-optimized 4-D trajectory planning”. The ATM system not only shall be designed to accommodate all type of aircraft but also be designed to optimize performance for a particular aircraft. The constant updating of shared information is the key to dynamic optimized planning.

In the ICAO Concept, “collaborative decision making will ensure that aircraft and airspace user system design impacts on ATM are taken into account in a timely manner”. Introduction of new aircraft types (and indeed new types of airspace user activities) can affect existing ATM resources or require new resources. Part of collaborative decision making is ensuring that the ATM system is prepared for these new types and activities.

In the ICAO Concept, “aircraft should be designed with the ATM system as a key consideration”. This is a two-way responsibility. The first is that the ATM system should make its requirements known to aircraft designers in a timely manner. The second is that the aircraft be designed with an understanding that the aircraft must be able to interact with the ATM system in an appropriate way.

Conflict Management

There are a number of changes to current ATM practice contained with the ICAO Concept on Conflict Management.

To prevent collisions between aircraft is now the function of Conflict Management which is “to limit, to an acceptable level, the risk of collision between aircraft and hazards”. Of course, the objective is still to prevent collisions, but in a performance-based ATM system an attempt to quantify the risk is needed.

“Conflict” has been redefined by the ICAO Concept to “any situation involving aircraft and hazards in which the applicable separation minima may be compromised”. This is what would have been called “potential conflict” in the current system and reflects a move towards a more strategic solving of conflicts.

The ICAO Concept introduces no new hazards – however they are now more explicitly stated in one group and are “other aircraft, terrain, weather, wake turbulence, incompatible airspace activity and, when an aircraft is on the ground, surface vehicles and other obstructions on the apron and manoeuvring area”. Work on systems such as Airborne Separation Assistance Systems (ASAS) have commenced work on separation from other aircraft and acknowledge the other hazards but consider they are beyond the scope of current ASAS work. It is important to note that complete separation systems require separation from all hazards; as the solution to avoid one hazard must also be clear of any other hazard of any type.

The ICAO Concept makes explicit the current processes of separation provision by defining separation modes (rules, procedures, conditions, etc) and associated separation minima. Future work will be defining these modes, include work on separation from weather and air to air separation. This work will also be necessary for the automation expected in future ATM systems because a conflict free trajectory cannot be determined unless the applicable separation modes and minima are known to the automation.

The ICAO Concept defines three layers of conflict management – strategic, separation provision and collision avoidance. Strategic is simply “in advance of tactical” and strategic conflict management techniques can be used after departure.

When a airspace user’s trajectory is changed, the ATM system will determine the best means of conflict management for that trajectory.

In the ICAO Concept, “strategic conflict management will reduce the need for separation provision to a designated level”. Not only will strategic separation be the norm in the future ATM, but any remaining tactical separation will be part of the ATM system design. This means that tactical intervention for separation (whether by the airspace user or the service provider) will be no more than a pre-defined amount – and the ATM system will act to make sure that this level is not exceeded. The ICAO Concept states that tactical separation (separation provision) “will only be used when strategic conflict management cannot be used efficiently”.

In the ICAO Concept, “the ATM system will minimize restrictions on user operations; therefore, the predetermined separator will be the airspace user, unless safety or ATM system design requires a separation provision service”. If the ATM system determines either for safety or design that a separation provision service is needed, then it does not mean that the airspace user can become the separator simply on request. In the first case (safety), it has already been determined that the airspace user is not an appropriate separator on safety grounds. In the second case (design) it has been considered for reasons of ATM performance that the airspace user is not the best separator. This is not to say that there are no cases where the delegation of separation to the airspace user is possible, for clearly that is allowed for in the types of separation provision and in delegation of separation – however it would have to be part of the second case and be part the ATM system design (that is procedures defined for when it will occur).

In the ICAO Concept, “the role of separator may be delegated, but such delegations will be temporary”. There are requirements for delegation in the ICAO Concept. It is important to note that it is not reasonable to assume that separation can be “handed back” before the termination condition. It may be possible, subject to negotiation, but it is not guaranteed. An acceptance of the delegation is also an acceptance of the whole period of the delegation.

In the ICAO Concept, “in the development of separation modes, separation provision intervention capability must be considered.” The separator can be the airspace user, a service provider or automation. “Separation provision intervention capability refers to the quality of humans and/or systems to detect and solve a conflict and to implement and monitor the solution.” The intent is that the best separator for a given situation is chosen.

In the ICAO Concept, "the conflict horizon will be extended as far as procedures and information will permit". This is to ensure a strategic approach to conflict management while recognizing that procedures will determine the appropriateness of how far to look ahead and that information may also limit how far in advance conflicts can be detected.

In the ICAO Concept, "collision avoidance systems will be part of ATM safety management but will not be included in determining the calculated level of safety required for separation provision". In other words, the safety net of Collision Avoidance Systems (CAS) does contribute to overall ATM safety – however CAS will lose value as a safety net if CAS are included in the level of safety required for separation provision (which is the separation layer above).

ATM Service Delivery

In the ICAO Concept, "the role of ATM service delivery management will be to coordinate the delivery of services from all service providers ... in response to an airspace user's request for a service" and "at the strategic level ... will be responsible for conducting collaborative decision making within the ATM community to achieve the best outcomes for the ATM community".

ATM Service Delivery should be on a regional basis, and to work with other ATM Service Delivery functions to form an interoperable global network.

In the ICAO Concept, "services to be delivered by the ATM service delivery management component will be established on an as-required basis subject to ATM system design. Once established, they will be provided on an on-request basis." Note this does not mean that the airspace user can necessarily choose not to use the separation provision service. This is a statement about the total services incorporated in the ATM system design, and the "request" for the service could be the outcome of a safety or efficiency need.

In the ICAO Concept, "ATM system design will be determined by collaborative decision making and system-wide safety and business cases". The collaborative approach is essential to the success of the concept. System-wide is also important as it ensures that the needs of all ATM community members are taken into account. The term safety and business cases has become "performance cases", which means that safety, cost-effectiveness, etc. are all considered together.

In the ICAO Concept, "services delivered by the ATM service delivery management component will, through collaborative decision making, balance and optimize user-requested trajectories to achieve the ATM community's expectations". Although the airspace user's preferred trajectory is recognized as the best outcome for the airspace user, trajectories will be collaboratively modified when necessary to meet all the ATM community's expectations.

In the ICAO Concept, "management by trajectory will involve the development of an agreement that extends through all the physical phases of the flight". The trajectory may even be from overnight parking to the gate and on for the rest of the flight. The intent is that for all interaction with the ATM system for a flight, the default means of management will be by trajectory.

TRAJECTORY MANAGEMENT

On page 1 of this statement is:

"The proposed solution to addressing the safety, environment, capacity, flexibility and efficiency needs of the future ATM is:

1. The Airspace User shall plan their preferred 4-D trajectory, and,
2. The ATM system will modify that trajectory to the minimum extent possible.

The difficulty with the proposed solution is that most of the states and service providers consider this is what they have always done and are still doing today!"

It is therefore appropriate to conclude this statement with comments on Trajectory Management.

Background

Air Navigation (and therefore Air Traffic Control which was designed to support it) has always and will always be about 4-d trajectories. It is inappropriate, especially when dealing with capacity issues, to discuss 2-d or 3-d ATM "solutions" – as the aircraft's effect on ATM resources is always 4-d.

Even today's ATM system with its problems is a form of advising the airspace user of the current ATM restrictions on available trajectories (via NOTAMs and published routes) and allowing the airspace user to "choose" their preferred trajectory (flight plan) with this level of understanding. Then that preferred trajectory is modified to the minimum extent (for there is no "value" to the service providers in modifying the trajectory any more than they have to – except perhaps to avoid the cost of providing extra capacity).

"Free-flight" (in its various forms and recreations) and "user preferred trajectories" invokes feelings of freedom. However, in any community, including the ATM community, your freedom to do as you please extends only as far as when your activity starts to affect another entity in the community. To provide a specific example: long delays were being experienced on a long-haul load-critical route, so the route structure was expanded so that 5 parallel routes were available. The problem was that on each day of operation, the airspace users all chose the same route as most efficient so there was no operational difference, just different routes in use. There may not have been any difference if there had been no routes, only user trajectories, as the airspace users would again simply all choose the same solution.

So, the next part of the solution is "user preferred routes and user separation" – however separation provision is not only "missing other aircraft" (which all are planning to be in the same vicinity anyhow) but also avoiding the other hazards listed in the ICAO concept. Like 4-d trajectories, self-separation has been in effect for many years around the globe and will continue to be. However, at certain traffic levels ATM design has often required a separation provision service, and although the areas so served may be collaboratively reviewed, it is likely for some time yet that a separation provision service will continue to be specified.

An interim step between fixed tracks and no tracks has been the flex tracks systems that generate a "route structure" on a 12-hour basis. The winds and other weather, as well as the expected aircraft types, number of aircraft, etc. are taken into account and the most efficient routes defined. This has been mainly for long haul flights and has delivered considerable savings to airspace users over the traditional fixed tracks systems.

Part of the reason behind implementing some flex tracks was that service provider's equipment could not work without routes (that is route-based flight data processing, not geographically based). Before more flexibility can be given to airspace users to choose their own routes, service providers' systems must all be geographically based systems. However even with geographically based systems it is expected that some fixed routes and some flex-tracks will continue to exist in future systems – when needed for safety or some other ATM system design requirement.

ATM Trajectory

What is needed is not only a vision of a wonderful future of trajectory exchanges and "free flight", but also the practical steps from here to there. To this end, the "ATM trajectory" should be considered as already existing, but it should be in a process of continuous improvement so that it serves both airspace user and service providers more efficiently.

A distinction needs to be made between the "trajectory" in the flight management system of the aircraft (or the airline's system) and the ATM trajectory. The ATM trajectory is based on the airspace user's trajectory, but it has "tolerances" that will be used unlike any tolerances in the current ATM system (but are similar to "block levels" and "cruise-climb"). They are in effect "freedom of flight tolerances".

Another significant issue where high precision is required is that different flight management systems describe different paths through the airspace, for example for the same standard instrument departure or arrival. For example, how a "fly-by" point is flown is handled differently in the various systems. Clearly the ATM trajectory must define a single path as the reference trajectory (and then "freedom-of-flight" tolerances as appropriate). The avionics can then fly a trajectory contained within those tolerances.

"Freedom-of-Flight" Tolerances

ATM tolerances have traditionally only been used to limit the uncertainty of an aircraft's position, but many aircraft now have highly capable navigation systems that have very small "uncertainty of position".

The new concept of "freedom of flight" tolerances is intended to allow an aircraft the freedom of movement within a moving volume of airspace, and the precise navigational tolerances allows the certainty of containment within that volume.

The ICAO Concept (Appendix I) provides explanations and examples of what the future may be and in these examples the tolerances are described as follows.

> *"6.14 This trajectory will be approved with tolerances, which will constitute a "4-D trajectory contract" between the airspace user and the service provider. The airspace user can accept or reject the proposal, as part of the collaborative decision-making process.*
>
> *6.15 The intent of these tolerances, which can vary over the trajectory, is to allow some freedom for changes within the trajectory to be made by the airspace user without further reference to the service provider. The tolerances are intended to provide as much flexibility as the ATM system can allow, while balancing the requirements of other airspace users."*

Consider the case of an oceanic flight in low density operations. The ATM trajectory will provide a large volume around that aircraft, for example allowing the aircraft to change levels or reduce speed due un-forecast turbulence, divert left or right of track around weather, etc. without reference to ATM – provided that the aircraft remains within the "freedom of flight tolerances".

There may of course be crossing situations in that oceanic volume that would require some accuracy at a particular point of flight, but the "freedom-of-flight" tolerances would only be limited for that period.

It is not only for such oceanic areas, but even in high density operations. For example, it may be that the airspace user wants some freedom of level restrictions to have the most economic descent profile. The airspace user might be willing to have almost no "freedom-of-flight" in the other dimensions (that is to follow a precise route at a precise time) provided that there is some flexibility in required level precision during descent. Another example is flexibility laterally when avoiding thunderstorms – but remaining under own navigation not radar vectors because of precise behaviour in other dimensions.

Trajectory Contract

The trajectory contract is mentioned several times in this statement. It is essentially an agreement for the airspace user to be at a particular location at a particular time (within freedom- of-flight tolerances) and in return the services and resources needed by the airspace user will be available. This is behind the term "on time, first served" priority. The airspace user makes good the promised performance, even if for example the winds are slightly different to forecast.

The trajectory contract also allows more strategic conflict management, so that inefficient tactical solutions do not "suddenly" occur.

The trajectory contract is modified during flight – both at the request of the airspace user and the service provider. It would be expected that the number of modifications would be monitored by the ATM system as an indication both of predicability of the system – and its flexibility!

The “trajectory contract” process is not a race where the first to get an agreement or the first to departure is guaranteed the agreed trajectory. There will continue to be airspace users who have short-term requirements on the ATM system – whether this is a new flight or a modification to an existing flight. Part of the ATM service is to balance the needs of all airspace users for access, for predictability, for flexibility, for efficiency, etc. As such re-negotiations of trajectories can be expected during flight.

The other reason trajectory modifications will be required is that the ATM trajectory evolves throughout the flight. When the aircraft is at the overnight parking position, the precise time of arrival at the destination gate is not fixed and known. The trajectory is refined over time, both by the airspace user and the ATM system - for example, when the departure gate is known. It is expected that the entire ATM system will become more strategically based, so that with increased predicability gates and other ATM resources can be allocated well in advance. It is likely that much of the initial trajectory will be “planned but yet to be confirmed”, so that gates, runways (using forecast wind, etc.) will be assigned, perhaps for the whole flight. However as there is a need to re-allocate resources (a different gate or runway) the trajectory modification process must be designed so that changes can be rapidly made.

The time element of the 4-d contract seems to have always been a part of air traffic control methods. As described in ICAO PANS_ATM (Doc 4444) “separation may be established by requiring aircraft to depart at a specified time, to arrive over a geographical location at a specified time, ...”. The 4-d time element is an important part of strategically managing traffic – even after departure. The ATM system needs to be able to use time precisely for this purpose, for example accuracy to within a second of time, and when required a requirement within 15 seconds of the time.

CONCLUSION

IFATCA considers that the best way to address the problems being experienced in ATM is by all members of the ATM community cooperating. The cooperation required is a serious working together that requires pragmatism and compromise by all involved. This involves collaborative decision making that requires involvement in the process and in the consequences. It requires commitment to change and a will to act at all levels including at state level.

IFATCA stresses that this approach of cooperation and commitment to act is more important than the final technology or procedures that will be implemented.

IFATCA considers that it has the experience and expertise to participate and assist in the process of making the future ATM system we all need.

APPENDICES

Appendix 1 – ICAO Concept

In 2004, the International Civil Aviation Organization (ICAO) 35th Assembly endorsed the "Global Air Traffic Management Operational Concept" (ICAO Doc 9854).

The ICAO Concept states:

> *"The global air traffic management (ATM) operational concept presents the ICAO vision of an integrated, harmonized and globally interoperable ATM system. The planning horizon is up to and beyond 2025. The baseline against which the significance of the changes proposed in the operational concept may be measured is the global ATM environment in 2000."*
>
> *"It is crucial that the evolution to the global ATM system be driven by the need to meet the expectations of the ATM community and enabled by the appropriate technologies."*
>
> *"A key tenet of the operational concept is performance orientation."*

The ICAO Concept lists the eleven expectations of the ATM community as:

- Access and Equity
- Capacity
- Cost Effectiveness
- Efficiency
- Environment
- Flexibility
- Global Interoperability
- Participation by the ATM Community
- Predictability
- Safety
- Security

The ICAO Concept lists seven components of the ATM system (that must all be used as an integrated whole):

- Airspace Organisation and Management
- Aerodrome Operations
- Demand and Capacity Balancing
- Traffic Synchronisation
- Airspace User Operations
- Conflict Management
- ATM Service Delivery

The ICAO Air Traffic Management Operational Concept Panel (ATMCP) drafted the ICAO Concept and was then reformed as the Air Traffic Management Requirements and Performance Panel (ATMRPP).

ATMRPP have since produced the following documents:

- ATM System Requirements Supporting the Global Air Traffic Management Operational
- Performance Based Transition Guidelines.

ATMRPP is continuing to work on the "Global ATM Performance Manual"; to be released in December 2007.

It is also worthwhile to remember to the preamble to the convention that established ICAO.

> *"WHEREAS the future development of international civil aviation can greatly help to create and preserve friendship and understanding among the nations and peoples of the world, yet its abuse can become a threat to the general security; and*
>
> *"WHEREAS it is desirable to avoid friction and to promote that cooperation between nations and peoples upon which the peace of the world depends;*
>
> *THEREFORE the undersigned governments having agreed on certain principles and arrangements in order that international civil aviation may be developed in a safe and orderly manner and that international air transport services may be established on the basis of equality of opportunity and operated soundly and economically:*
>
> *"Have accordingly concluded this Convention to that end."*

(Preamble to the Convention on International Civil Aviation)

This statement on the future of global ATM is calling for a renewed commitment to these principles, for without cooperation and the political will to act, especially at state and regional levels, the current problems in Air Traffic Management will only deteriorate further.

Appendix 2 – IFATCA

The International Federation of Air Traffic Controllers' Associations is the worldwide organization representing more than fifty thousand air traffic controllers in over 135 countries.

IFATCA was founded in 1961 with the objects of:

a) To operate as a non-profit and non-political federation of air traffic controllers' associations;
b) To promote safety, efficiency and regularity in International Air Navigation;
c) To assist and advise in the development of safe and orderly systems of Air Traffic Control;
d) To promote and uphold a high standard of knowledge and professional efficiency among Air Traffic Controllers;
e) To protect and safeguard the interests of the Air Traffic Control profession;
f) To make mutual benefit affiliations with other international professional organisations;
g) To strive for a world-wide Federation of Air Traffic Controllers' Associations.

IFATCA considers it has the experience and expertise to assist in addressing the problems being experienced in Air Traffic Management and in moving towards an efficient future ATM system.

IFATCA strongly supports ICAO as the organisation that coordinates global ATM activity.

IFATCA has initiated this statement on the future of Global ATM as another step that builds on the ICAO Concept. Many more steps remain.

In the spirit of cooperation, which is so essential to success, IFATCA seeks support of this statement on future ATM so that it can represent not just IFATCA's position but an agreed position with many organisations concerned with current and future ATM systems.

Appendix 3 – Current ATM Problems

The objective of listing the problems with today's ATM system is not so that someone can be "blamed", but rather list what is needed to be addressed by the whole ATM community.

Various lists have been compiled of the problems with the current ATM system (for example ICAO Concept Appendix C). It is not intended to repeat them all here.

There are also a wide range of needs and environments, and a problem in one area is not necessarily a problem in another area.

The problem is not a requirement for "new" or "advanced" technology - in that existing technology could be used to address most of the needs. The solution involves using technology, especially existing technologies, efficiently.

The problem is not necessarily one of finance either. Much of the "budget" of proposed solutions is acquiring and implementing "advanced" technology (including training staff, etc) – but many changes can be made via procedures with existing technology. In any case, with the proposed system-wide business cases it should be easier to fund changes to ATM.

Performance measures are also not the answer – for using performance measures to try and force changes will not bring about the needed improvements. (Performance measures can be very useful tools – just not good whips.)

Commitment to cooperation and change is the key and the biggest factor – including political will at state level and regional level. Also, few solutions are going to achieve their full potential without the commitment to cooperation and change by the military, which has already been seen in some parts of the world but often requires action at state level first.

Perhaps the next biggest problem is that "ATM service provision" is seen as an impediment to efficient operations – instead of its role which is an enabler of efficient operations. Some of this is perception; some of it is a failure to communicate meaningfully; some of it is the inefficiencies in service provision systems.

Inefficiencies are especially evident between service providers. A radar service stops not because the aircraft is out of radar cover but because of a change of service provider and because the radar data is not shared. "Advanced" air traffic control systems are unable to exchange flight plan data with the adjacent "advanced" system – and what is very bad is that the service providers actually believe that it cannot be done (due to technical problems that cannot be overcome)! Other air traffic control systems have examples of difficulties even telling the adjacent unit that the aircraft is coming (that is ATC coordination). How can there be discussions of "System Wide Information Management" and "trajectory exchanges with aircraft and service providers" when it has not yet been demonstrated how this data sharing is already achieving benefits between ground systems? No wonder there has been many calls for "fewer service provider centres", for seamlessness and interoperability, for single system approaches. The ICAO concept defines ATM as "the dynamic, integrated management of air traffic and airspace — safely, economically and efficiently — through the provision of facilities and seamless services in collaboration with all parties". Clearly this is the hope of the future ATM system.

Inefficiencies also exist within service provider systems. Having "combined centres" is not a solution in itself. Examples exist where "integration" has occurred years ago – but all that was achieved was standardization at the equipment level (which was a very small gain for such a big effort). The operating methods and procedures throughout the room are far from standardized despite the passage of time. The inability to exchange current trajectory information between sectors using the same hardware can also exist within centres.

Another problem is that services did not evolve with the equipment. Examples are known for cases where the ground system did not support advances in aircraft systems, so examples about ground systems only are provided. For example, there are several places around the world where radar seems to be used to monitor procedural standards rather than apply radar services. There are also cases where service providers have progressively updated their radar systems, but essentially their use of the radar for control did not change (though radar displays improved with alarms, etc. and other "tools" for controllers) Monopulse radar is much more accurate in bearing detection than the earlier generation "first-detected and last-detected" systems – however this does not seem to be have been used to great advantage in re-examining the radar standards used or for looking for ways to use this improved accuracy other than the traditional radar use as it was first deployed 30 or 40 years ago. (This is despite many programs looking at using increased navigation performance of aircraft for "improving" service provision.) How best to use the increased surveillance accuracy from systems such as ADS-Broadcast is only just starting to be debated.

Do not forget that much that is good is done every day by service providers, and that there already exists some cooperation within the ATM community. It is truly amazing that the ATM system today works as well as it does on global, regional and local levels and the level of interoperability that is achieved. But there are improvements that must be made by ATM service providers to prove the benefit that they deliver and re-establish a respected position – and this must be done with the cooperation of all the ATM community.

One way of describing teamwork is that each member of the team does whatever they can to make it as easy as possible for other members of the team to perform at their best. The cooperation at all levels of ATM should seek to achieve precisely this.

Appendix 4 – Language of ATM

The language of ATM needs to evolve as the ATM system itself evolves, at all levels of the ATM system.

The need to communicate across different interests or different disciplines has always existed. For example, consider engineers and air traffic controllers. These disciplines must work closely together in designing, installing and operating air traffic management equipment. As a generalisation, engineers as a starting point want to discuss the environment (usually a closed or controlled environment) in which the equipment will operate and then describe "normal operation". Controllers by nature like to discuss systems in terms of exceptions as controllers often consider "normal behaviour" to be "self-evident" and do not expect the system to be a closed system. Controllers want to know how exceptions to normal behaviour will be able to be handled.

It is not impossible to communicate across a discipline or interest boundary – and the best means is usually "interpreters" who are experienced in both disciplines. Note: Simple translation is not the aim, but rather interpretation that communicates meaning, not just words.

Interpretation is not for "public relations" or basic "selling an idea" – interpretation is to enable the disciplines to work together.

A major failure of current ATM is the failure to communicate at senior levels of management about the essentials of air traffic operations. In the early days of ATM, communication and understanding were perhaps simpler. Often senior staff of air traffic service providers had a flight- crew background, and they communicated with the chief-pilot of the airline. Today senior management is often reflected in both organisations by accountants and lawyers. The language of ATM needs to evolve to communicate across these disciplines. For example, air traffic service providers have often evolved from being combined with a regulator and so their major catch-cry is "for safety". From a business orientation, safety is a given. It does not matter whether you are selling food or airline tickets; if the product or service is not safe then you will not be able to trade. This does not mean that safety is not important, instead it is acknowledged as essential and that it is why it is assumed as a pre-existing requirement. A similar situation is that air traffic control is described as "preventing collisions between aircraft" – but a focus only on this causes a problem in communication. For example, this can lead to a misunderstanding that if an airspace-user self-separates then it means the end of "Air Traffic Control (ATC) delays" and an end to Air Traffic Service Providers (ATSP) charges.

Air Traffic Management should be communicated as a resource management service for a finite resource. The ATM service-provider administers the resource on behalf the resource owners (the state for airspace and the airport owner for aerodromes) – and has responsibilities to these owners. The ATM service provider is increasingly a business (or must operate as if it is a business) and so also has other financial and legal responsibilities. (See Appendix 3 – "The evolving Air Traffic Service Provider".) The service provided is the allocation of aerodrome and airspace resources in a manner that provides for the (safe) orderly and expeditious/efficient flow of air traffic – and the service-provider should be able to prove that it does this more efficiently than airspace-users can do for themselves.

Appendix 5 – The Evolving Air Traffic Service Provider

The Air Traffic Service Provider (ATSP) has undergone considerable change, but some of the biggest changes are yet to occur.

This section will discuss mainly the provision of Air Traffic Control.

Initially it was common for the regulator, ATSP (ATC) and aerodrome owner to be a government department, for example a department of civil aviation. When the ATSP wanted to have a particular level of aircraft equipment, this was achieved by regulation. If changes were needed to aerodromes (for example changes to lighting) this was directly under the ATSP's control. Safety was the reason quoted for everything. Funding of long-term projects was often difficult (as funding depended on government allocation).

Increasingly the Regulator and the ATSP (ATC) are now separate organisations, and the aerodromes have non-government owners or operators. The ATSP must either be a business (for example, a government-owned or private corporation) or must act as if it were a business (for example, not-for-profit organisation or user-pays government department). The "government funded public service" ATSP is disappearing. The ATSP can no longer by themselves have changes made to aircraft equipage by regulation, and similarly cannot "control" changes to aerodromes. At least long-term funding for non-government ATSPs is less of a problem.

As an independent business now responsible to the regulator, ATSPs can expect increasing regulation of their activities – and this will include items such as certification standards for their equipment (previously not even a question when combined as a government department). However managing an ATSP's behaviour by the regulator having the power to suspend (or in extreme cases revoke) the ATSPs licence is not effective unless there is another ATSP that can take over from the suspended ATSP. At least one regulator has recognised this and as part of the licence conditions of the ATSP, an alternative ATSP must be nominated (and a formal arrangement put in place). This is to ensure continuity of services.

For reasons of regulation and recognising the monopolistic (at least from a state level) of ATSP, it is to be expected that it will not be long before multiple ATSPs operate in any given state's airspace. This will be easier with the changes in future ATM that manage all airspace without restrictions based on state boundaries, the exchanges of ATM data, etc. The ATSP will truly become an international business and have to deal with multiple legal jurisdictions, just like any other international business.

Other possibilities exist under future ATM concepts. The ATSP in order to continue to trade must be able to convince its customers that it supplies a service worth buying. In other words, that the ATSP can do something for the airspace user more efficiently than the airspace user can do it for themself. If there is "self-separation" airspace, but an ATSP has convinced the airspace user that they can do the task more efficiently (and can meet the regulators requirements), then the task of separation may even be done by the airspace-users choice of ATSP. This would result in multiple ATSPs for the one volume of airspace.

Just as there has been the commencement of "low cost carriers" airlines, it is also possible for the development of "low-cost air traffic service providers". Examples can be drawn from government telecommunications companies that have been privatised and then required by the government to provide access to telecommunication network resources so that competition from other suppliers can occur. This means that government regulations may require infrastructure (such as a radar data network) of an ATSP to be made available to competitors.

It used to be believed that a government would never let a state-owned airline to go out of business – but this has happened. It is also wrong to assume that a government would always support a "national ATSP". This is especially true when an effective set of laws and regulations have been established by the state. It would be as easy for the state to regulate several ATSPs as it is for one, and ATSPs could be identified as potential sources of government income where the right to use airspace by offering a service enabling its use is seen in the same way as government "selling" the right to use certain frequencies (for example 3G telecommunication networks).

Due to some of the possibilities mentioned above, there has been discussion that there may only be a few ATSPs globally. While this is possible, it is more likely that ATSPs will for many years continue to exist as independent entities, however they will form alliances (for example, to develop or purchase common ATM systems). The improved sharing of data will make it less significant to have "mega-centre" solutions, as smaller units will be able to inter-operate seamlessly.

While the above has talked of ATSP (ATC), in the ICAO Concept the term ATM service providers (SP) is used. The definition is broad (any "ATM service to airspace users") and so provides opportunities for SP to develop new products for its customers.

The changes occurring in ATSPs should not affect the functionalities being described in the vision and concept of operations. However the development of business plans involving ATSPs will have to be aware of the changes that are occurring at the time.

Appendix 6 – Pragmatic Airline Expectations

Above under Cooperation it states: “Pragmatism also requires a reasonableness that does not demand more of others than you are willing to offer yourself. “

Airlines are increasingly demanding that Air Traffic Management provide them with departing when they are ready, direct tracking between departure and destination and no holding.

If the flying public was asked what they wanted from airlines they would reply in the same way! There is no doubt that the convenience of departing when you are ready, travelling directly from departure to destination and no delays is a universal desire when travelling (or shipping freight).

However, what is left unsaid is that this is not “at any cost” as, whether travelling for business or pleasure, the activity has to be economically reasonable. Some can afford the expense of their own aircraft (or chartered aircraft) however for most of the flying public they are willing to accept varying levels of inconvenience in return for a cheaper ticket.

So, consider the example of a person wanting to travel from A to B. No airline flies direct, but for airline efficiency or other reasons, the person must travel via another point (for example a hub and spoke system) so that they travel from A to C to B. This is true even if buying a first-class ticket. In addition to the delay of not travelling direct, the person has to queue a number of times to check-in, to clear security, to wait for boarding – and may even have to repeat the security and boarding procedures at C due to a change of aircraft. Even after the flight, queuing is required waiting for checked luggage. Airlines know that passengers do not like these delays and take steps to minimise the delay – but no one is expecting the airline to employ many staff and have much infrastructure so there is always “direct tracking with no delay” for the airline passenger.

This is not a problem related solely to ATM – for queuing is found in many activities during peak demand and in cities restrictions are placed on where you can walk or drive.

Air traffic service providers need to continue to “reduce the delay” knowing that their customers (the airlines and other airspace users) do not like delay – and airlines should appreciate from their own experience and operations that there are efficiency and other reasons why not all flights can have “direct tracking with no delay”.

In pragmatic discussions on ATM solutions, realistic expectations of how much the delay can be reduced are needed.

Appendix 7 – Evolving Ground Systems

ATM ground systems have generally lagged behind development of airborne systems. This is changing and ground systems can now evolve very rapidly.

Traditionally civilian ATC systems used expensive proprietary equipment. For example, when buying a radar system, the analogue radar head would only interface with that same supplier's radar data processor, display processor and screens. Upgrading of systems was so expensive that it was delayed – sometimes until the lack of spare parts forced a major upgrade of the system. Improvements made to the old system were not carried forward in the new system.

The situation is different today where advances outside of the ATM are available to be used. Admittedly radar heads and processors are still an ATM industry – but the output is digital data. The computers to process the radar data, the network connections, the display processors and screens are developed outside of ATM for a wide range of applications – and the broader market use of these components will mean further improvements will be made.

A major aspect of the change is that components can be upgraded in the system without major change to the overall system. For example, a new computer can be installed using existing software and performance improves.

Changes to components are not limited to hardware. For example, an additional functionality can be included in the software. The significant advantage is that the user of the technology (for example the controller) does not need to learn to use a completely new set of equipment as everything is as it was before – except for the added functionality which of course will require some training.

Computer software for ground-based systems is an area where significant improvements can be made – but these can be rapid incremental improvements if needed.

Appendix 8 – Prevention of Collisions

Clearly the pilot in command of an aircraft is responsible for the safety operation of the aircraft – and so must avoid collisions.

Clearly the air traffic controller's first defined task is "to prevent collisions between aircraft".

However, neither the pilot nor the controller is the agent assigned responsibility if one of the aircraft is fitted with an Airborne Collision Avoidance System (ACAS), for example TCAS. It has recently been reiterated that the pilot must follow the instructions (resolution advisories) issued by ACAS and that the controller must not issue any instructions that modify the trajectory of the aircraft.

Clearly the ACAS system has been assigned responsibility for preventing collisions.

The ICAO definition of air traffic control uses the term "prevent collisions". This definition has caused some legal difficulties as in one jurisdiction the exact ICAO wording was copied into local legislation. The judge ruled that despite the aircraft not following the controller's instructions (which in the judge's opinion only explained how the aircraft got to their position), the controller clearly did not prevent the collision and so was the majority to blame (60%) with the pilots who did not follow the instructions assigned 40% responsibility.

Although the ICAO definition of Air Traffic Control has not yet been updated, consistency with the ICAO Concept would define air traffic controllers as responsible for separation provision – and that collision avoidance is another layer below separation provision.

No system, human or technology, can guarantee to "prevent collisions" – though that of course is the goal and perhaps will remain the politically correct way of discussing collisions. However, in serious discussions it needs to be recognised that collisions will occur. In discussions on setting parameters for TCAS it was acknowledged that TCAS may even contribute to some collisions – but that its value was that it would prevent many collisions.

The reliance on ACAS is of concern because there seems to be no comprehensive record of ACAS performance – for example the number of "false" alerts (as a separation standard was in place), etc.

In addition, although ACAS carriage is mandatory for some airspace, aircraft can operate with ACAS unserviceable awaiting repair.

A significant problem is the design of Secondary Surveillance Radar transponders now in operation that either transmit mode A and C – or nothing at all. The problem is when the mode C is in the error – as the pilot cannot select just mode A. If the transponder is on, then ACAS may generate false resolution advisory based on an incorrect mode C level. If the transponder is completely off, then ACAS will not even give a traffic advisory (as the aircraft without the transponder on is not detected).

Some Air Traffic Service Providers use only SSR surveillance in some areas and one has issued instructions that in such cases of Mode C being in error and either all on or off that the aircraft should continue to operate with the incorrect Mode C. No consideration seems to have been given to false ACAS alerts.

It is proposed in some areas that flight deck automation be responsible for following the ACAS resolution advisory. Careful analysis of current ACAS performance is required before taking such a step. Note: RA would then definitely not be an “advisory” but instead a “command”.

Security is also a concern. For example, malicious activity could operate a transponder with false mode C under a holding pattern.

A consistent ATM design is required for automated collision avoidance systems with appropriate monitoring of the automation’s performance.

Appendix 9 – Flexibility and Capacity

Flexibility is the ability to accommodate change, whether or not that change is discretionary.

ATM Flexibility is related to capacity, for as unused capacity reduces so does flexibility. If there is no spare capacity, then flexibility is limited to exchanging one “slot or use” for another – and even this may not be possible as the resulting disruption to the flow of traffic could cause a further reduction in capacity.

ATM Capacity should be viewed as resource management of a finite resource – which is the airspace or the aerodrome. Capacity is related directly to how much of that resource is “in use” by each operation. “In use” applies in four dimensions for it is not only a three-dimensional volume surrounding an aircraft but also time. For example, for departing aircraft initially following the same departure track when a slower aircraft departs first and takes a greater time to clear the departure path of the faster following aircraft, then departure runway capacity is reduced.

Increased accuracy in navigation results in an increase in capacity, as the uncertainty of the position of the aircraft reduces. This has been used for lateral and vertical segregation and separation. The notable exception has been time, which affects longitudinal segregation and separation. Accuracy of time within the ATM system is capable of synchronisation to less than a second, for example by using Global Position Satellite (GPS). When required, for example high- density operations, time at a position should be able to be reported to the second, and requirements to be time over a position met within 15 seconds of the required time.

Separation standards are based on navigational capability or surveillance capability. It has proved difficult to establish a method for determining “safe separation” for even procedural separation standards used by service providers. The ICAO Concept requires the development of separation modes and minima for all separation provision (including separation provision by airspace users). The difficulty in this task should not be under-estimated, especially for a 10-fold increase in safety as a pre-requirement. When smaller separation standards are developed, there will be an increase in the capacity – both by the number of aircraft that can be accommodated and a reduction in the interventions required for separation.

Capacity is often discussed as number of aircraft in a sector and is to ensure a manageable workload for the controller. A common misleading statement is that the controllers’ separation workload increases with approximately the square of the increase in the number of aircraft, that is that 3 times the number of aircraft is nine times the workload. This statement is not necessarily true as it assumes that “potential conflicts” are conflicts (that is that all aircraft in the sector affect all other aircraft in the sector). The controllers’ workload relates to the number of interventions required. If there is an orderly flow of traffic and few interventions are required, then a large number of aircraft can be accommodated. However, for the same sector, if there is not an orderly flow of traffic (that is not strategically deconflicted or segregated) and so the controller has to frequently intervene then many less aircraft can be accommodated. The ICAO Concept states, “Strategic conflict management measures aim to reduce the need to apply the second layer — separation provision — to an appropriate level as determined by the ATM system design and operation”. In other words, ATM design is to determine and limit the number of tactical interventions required for separation – and this is true whether it is being done by a service provider or by airspace user (self-separation). Future ATM systems should not discuss capacity in terms of “controller workload”, or “sector capacity”, but instead discuss as one factor of capacity the number of “separation provision interventions required”.

Another issue of capacity is the mix of aircraft speeds, especially the size of the speed range. In other words, if there are a number of aircraft at a similar level but operating at different speeds (so there is closure between aircraft) then the number of interventions required will increase. This applies not only to cruise speed but also descent and climb speeds. Especially during climb and descent being managed by automation, the difference can be quite significant. Examples have been seen of closure of more than 20 NM between two aircraft of the same type and being operated by the same company arriving via the same route and given unrestricted descent from the same cruise level with no ATC requirements for speed control until 10,000 feet. So even the same type and same airline company traffic has affected both predictability and capacity, from the controller’s perspective in the current ATM system. There are several ways of solving problems of different speed, especially in a 4-d environment. The need for different speeds needs to be accommodated within current and future ATM systems – but does have a consequence on capacity and therefore flexibility.

High accuracy 4-d contracts can enable flexibility! The high accuracy is required to “use” as little of the ATM resource as possible (and therefore increase capacity). It seems contradictory at first to say that high accuracy increases flexibility but understanding the relationship between use of available capacity and flexibility is part of the answer. The rest of the answer to flexibility is:

1. When there is either a desire or need to change the highly accurate trajectory, that this is accomplished very quickly and smoothly.
2. 4-d contracts should also include tolerances which allow maximum use (balanced with the needs of other airspace users) of the ATM resource without trajectory re-negotiation.

Degree of flexibility available is determined by unused capacity. Capacity is determined by how efficiently the ATM resource of airspace (or aerodrome) is used.

Appendix 10 – No Directed Frequency Changes

A vision statement does not have to be long or complicated to have a powerful effect. Consider for example a vision of "no directed frequency changes".

There is an existing requirement for the pilot and the air traffic controller to be able to communicate directly by voice. Consider areas where Very High Frequency (VHF) radios are used. The pilot must be instructed when to change frequency, must read-back this frequency, must select the correct frequency and report on the new frequency. There are problems with obtaining correct read-back of frequencies and of selecting the wrong frequency. All of this work distracts both controller and pilot from their primary roles. As air traffic control sectors become busier and are split into smaller sectors, this workload of being on the correct frequency increases for both the controllers and pilots. If there was no requirement for directed frequency changes, think how much this would improve the workload of pilots and controllers.

Frequency congestion has caused the introduction of 8.33 kHz VHF spacing and caused much discussion about how best to phrase frequency change instructions. However, we still have no vision in place for removing frequency changes.

Suitable technology is already deployed in other areas. For example, consider Controller Pilot Data Link Communication (CPDLC). The pilot is required to initiate contact with ATC and logs on the ATC centre's CPDLC. All transfers between ATC centres are done automatically. The pilot usually has a display showing which ATC centre the CPDLC is logged on to. In addition, when logged onto an ATC centre's CPDLC processor, some ATC systems automatically transfer the messages from the pilot to the controller who is responsible for the aircraft at that time.

Another example of suitable technology is the mobile phone. A mobile phone user does not have to select a particular frequency to use and can move between mobile phone cells without losing contact. In addition, mobile phones do not require a "report on frequency" to establish if the call is still connected – as the mobile phone only reports if the connection was lost.

Such a system could be designed to allow the selection of particular frequencies by the pilot when required (in addition to having an ATC selection that automatically keeps the pilot in direct voice contact with the relevant controller).

When considering such options, it is important to realise that the radio calls achieve other tasks as well. For example, it verifies the assigned level and also reminds the controller that an aircraft has entered his area of responsibility (or left it). The additional tasks must be taken into account when re-designing the system. For example, datalink may be verifying the assigned level, and the controller's interface of hand-off and accept would remind the controller of an aircraft entering or leaving the controller's sector. However, such items as this do not preclude a vision of no directed frequency transfer.

Despite the issues of retrofitting, "no directed frequency transfers" should be evaluated as an important improvement to ATM efficiency.

Appendix 11 – On Time Performance

Air traffic control is about creating orderly and efficient flows of air traffic.

One of the most significant issues of current ATM separation service provision design is that the established flow of traffic immediately starts to deteriorate. The rate of deterioration is variable, but often significant. The deterioration is caused by variables (such as wind not being as predicted) and by actions of the airspace user and of the service provider (as individuals take tactical actions without awareness of overall system consequences). This occurs in all phases of flight.

Air traffic control is often viewed in terms of aircraft "conflict pairs" and actions to make them miss. This view has arisen because of a very tactical approach to air traffic control. However, the air traffic situation is not that chaotic, where any combination of aircraft can conflict. The aircraft has an airways clearance and cannot change its route and assigned level except on request (or in an emergency). Although the aircraft is cleared from departure to destination (in controlled airspace), a process of coordination between adjacent ground positions progressively authorises the flight to transit a sector of controlled airspace, but this coordination is all internal to the service providers. This "authorisation" to transit a sector is contained in written agreements (for example spacing/rate, levels, etc) or may be individually coordinated. Clearly this is not a random collection of aircraft pairs but establishing orderly flows.

Two aircraft can conflict in three ways – same direction traffic (but different speeds), crossing traffic and opposite direction traffic.

Consider the case of two aircraft travelling in the same direction at the same level at approximately the same speed. If the aircraft are near the minimum separation standard and either the first aircraft slows, or the second aircraft accelerates then the controller will have to act quickly to prevent a loss of separation. Surprisingly in a significant number of cases, aircraft can vary speed without advising air traffic control.

Consider the case of aircraft crossing at a point at the same level. Whether they will pass with separation or not (if there was no intervention) depends on the time they each reach the crossing point. Even if the pilots have nominated an estimated time for the crossing point (for example a position report in procedural (non-radar) airspace), they are not required to make good this time – unless it is an ATC requirement.

The uncertainty of the aircraft's position along its cleared route makes more strategic control of aircraft difficult and disrupts orderly flows of air traffic.

In a similar way, there is also uncertainty in the vertical profile, especially with rapid changes in level.

The need for "on time performance" is currently compromised in several ways. For example, a controller clears an aircraft direct - but then the gate is not ready on arrival because the aircraft is earlier than expected. In a similar situation, a pilot slows in cruise as the airline company has advised the pilot that the gate will not be ready – but the controller only observes that the aircraft is slowing and conflicting with other traffic.

One means of dealing with this uncertainty is a 4d trajectory contract. The aircraft would be expected to make good the trajectory and so be at nominated positions at the nominated times. Slight variations in actual wind to predicted wind would not be sufficient to vary the contract as the aircraft would vary its speed to make good the required times. Despite the change in fuel burn, an overall ATM efficiency is expected – that should save fuel burn occurring at unpredictable and inefficient times. The service provider would not vary the trajectory based solely on a short-term gain in one or two sectors. The whole ATM system will collaboratively ensure that needed resources and services are provided at the agreed times.

On time performance (4-d contract) is critical for ensuring ATM capacity is maximised.

Appendix 12 – Black Box Interoperability

One approach to interoperability between aircraft and the ATM system is the "ATM black box" approach.

The "ATM black box" would function in a similar way to a computer's operating system that interfaces between the specific hardware on the computer and the software application. Every aircraft would be equipped with a black box. "ATM" would design the application side of the black box and maintain it for global standardization. The aircraft manufacturers would be responsible for making connections (interfaces with their specific hardware and software) on the "hardware" side of the interface.

The challenge to ATM is to define the functionality that is required (a long overdue activity).

It does not mean that all aircraft would be capable of all functions. If an aircraft was not capable of an ATM requested function then it would give a suitable "NULL" response, etc. This way a common interface would exist between the aircraft and any other ATM systems.

Even if the solution of a black box for ATM is not the chosen solution, it is still useful to consider a "virtual" (or software based) equivalent.

Appendix 13 – Performance-Based ATM

Much work is currently underway in determining how best to have a performance-based ATM system, both at ICAO (see Appendix 1 – ICAO Concept) and in the states. This section will not summarise or repeat the current work but rather highlight a few points, to start with what ATM performance is not about.

A common mis-quote of the ICAO Concept is that the future ATM system will be performance **driven** (instead of correctly quoting that it will be performance **based**). The ICAO Concept talks of being driven only three times:

1. When discussing the current situation: "driven by safety and increasingly by commercial or personal outcome expectations".
2. When discussing the future situation: "driven by the need to meet the expectations of the ATM community".
3. When discussing scaling concept components: "driven by minimum safety levels".

This is not an issue of semantics – for it is not the performance measure (the number) that is the real goal, but rather to address the reason behind why this measure was set. So, the real goal of ATM is not to achieve a number (performance measure) but to meet expectations (by using performance measures).

Note: Another mis-quote of the ICAO Concept is to refer to the "Airspace User Expectations" instead of "ATM Community Expectations" – this is partly due to the large number of Airspace User related expectations in the list, however it remains the expectations of the whole ATM Community that is the driver and goal.

A significant concern is that "ATM Performance" cannot be allowed to become "Performance Pay" (or other remuneration or working conditions) – especially for any operational staff. This is because it appears that the human response in decision making is compromised in achieving a particular "numbered" result instead of achieving the best outcome overall – that is personal performance/outcome wins out over system performance/outcome. This is not considered desirable in operational areas of ATM.

Another significant concern is the lack of data at operational levels, for there is much discussion about overall ATM performance and yet little practical measurement of what the ATM system actually does.

The easiest to acquire would be expected to be automation performance. However, for example, serious discussions are occurring about Aircraft Collision Avoidance Systems (ACAS) without complete data on the ACAS performance. Fundamental questions about the number of RA generated etc are left in many cases to human reporting systems, and many events are not collected. In other cases of automated reporting, it seems too easy to dismiss the report as "not relevant" and then that statistic is no longer available in any form (whereas a robust reporting system should be able to report all occurrences and provide different ways of viewing the significance of events). There are concerns that such "classification" of events is at times used to produce a particular performance outcome (no more than x level 1s, no more than x level 2s, etc.), that is a reasonable data distribution rather than the data as it is.

Lack of data does not only relate to "abnormal" or "error" situations – but also for "normal" performance.

There is a lack of comparative data (how was today compared to yesterday, last week, last month, last year) – whether at senior or operational manager level and therefore almost no corrective behaviour (to mitigate negative and reinforce positive). There is a lack of balanced data – for example if there is so many minutes of delay in a sector (an inappropriate measure itself), where are the corresponding measures of minutes of oversupply of traffic to sector, number of aircraft over capacity, etc. – and what do they all mean anyhow? Can a manager at any level be asked "how is (your part of) ATM going today ..." and have a meaningful (comprehensive and balanced) answer?

An interesting measure of performance used on aircraft carriers is the rating of each landing by an observer. It would be an interesting experience to have feedback from each flight as to how effectively the services offered met the airspace user's expectations.

This section is not against ATM performance measures – instead it is stressing how important performance measures are to understand where ATM is and how far to where ATM should be. But do not expect 1, 10, 100 or even 1000 "numbers" to enable an understanding of ATM or even just to fix ATM. And be careful that the performance measures chosen and the way that they are used actually progresses towards meeting the community's expectations of ATM.

Measuring ATM performance at this time seems to be both a science and an art – for getting the right measures and interpreting them correctly is difficult.

Appendix 14 – ATM Capability Level Examples

The ATM system must support aircraft of different types and capabilities, so a means of indicating capability is required.

In addition, the whole ATM system must be capable (service provider and airspace user) – and so the whole ATM system must be able to indicate its capabilities as it evolves.

These examples are based on work initially done for aircraft capabilities in SESAR, but expanded into an example of ATM capabilities. They are indicative of the approach that aims to describe required functionalities rather than required technologies and defines the progressive evolution of ATM.

<u>ATM-1 systems will have:</u>

- To support collaborative decision making, basic information sharing:
  - High-accuracy, high frequency automated sharing of aircraft position information
    - For example: for aircraft ADS-B out, for service-providers capability for automated shared aircraft position data to airspace users and other service providers.
  - Basic automated event reporting
    - For example: for aircraft ADS-C consistent with To Be Defined (TBD) standards, for airline reporting changes in intended trajectory ("flight plan") status or details, for service providers changes in status of ATM resources – airspace, weather, capacity, etc.)
  - Basic airspace-user/service-provider datalink
    - For example CPDLC consistent with TBD standards.
- To support management by trajectory (including queue management and separation):
  - Controlled Time Over (CTO) function – single constraint (both airborne and ground systems)
  - Vertical and longitudinal constraint management to prescribed accuracies.
  - 2D-RNP (appropriate to the operation).

<u>ATM-2 systems will have ATM-1 capabilities plus:</u>

- To support collaborative decision making:
  - Trajectory sharing air/ground and ground/ground via functions designed for ATM
  - Increased airspace-user/service-provider datalink capabilities (for example: to support ADS-B in, CPDLC consistent with TBD standards, airline/service-provider datalinks)
- To support management by trajectory (including queue management and separation):
  - CTO functions – multiple constraints.
  - Functions related to Spacing/Sequencing and Merging
  - Vertical navigational performance requirements to prescribed accuracy
  - Vertical constraint management to prescribed accuracy
  - Longitudinal constraint management to prescribed accuracy.

<u>ATM-3 systems will have the ATM-2 capabilities plus:</u>

- To support collaborative decision making:
    - Meteorological data sharing.
    - Trajectory sharing: air/air
- To support separation management:
    - Longitudinal navigational performance requirements (appropriate to the operation).
    - Cooperative Separation functions
    - Self-Separation functions

Appendix 15 – Putting Ideas into Practice

This appendix gives some examples translating the concept terms into practical application.

Example 1 - High Density Radar Environment with Capacity Problems

Consider an environment where there is guaranteed radar coverage from multiple sensors, there are military requirements for airspace blocks and there are several states and service providers who wish together to implement some of the ICAO Concept. The major issue identified is one of capacity (and so flexibility). Delays in access to airspace and in transit are considered by the airspace users as excessive.

In this statement it has already been explained that capacity is tied to the amount of ATM resource used, the number of interventions required for separation provision, etc and of the ICAO Concept's move towards strategic separation.

Instead of insisting on higher precision navigation from aircraft that are already highly capable, the service providers determine that the best way to use less ATM resource per flight is to review the radar separation standards used. This is not only to implement a common radar standard amongst all the service providers, but also to use radar combined with the precision of aircraft navigation to create new radar surveillance route separation standards. (This is not "radar monitoring by controllers who intervene when it is not working – as this is tactical – but instead a strategic separation that proves the routes are separated under set conditions – which may or may not have automatic route compliance function.) Even without new standards, it is expected that a 3 NM radar standard could be applied – but the service providers are investigating if it can be reduced even further to establish strategic separation as soon as possible after departure.

Another major issue is the lack of direct routes due to airspace blocks used by the military. As an interim stage to a more comprehensive management by trajectory, the military agree that for any airspace block that significantly affects civil traffic, then an appropriate corridor structure would be established to permit civilian transits even when the areas are active. This involves collaborative decision making by the military, airspace users and service providers. The states have advised service providers and the military that the costs of civil diversions around military areas must be monitored and discretionary military activities modified so that they do not unreasonably affect civil traffic.

The following steps detail the action plan for implementing the strategic separation and reducing the amount of ATM resource used by each flight, while improving safety.

1. As the target ATM environment is high-reliability radar surveillance, determine separation standards to be used in such an environment. Develop new separation standards, this includes radar lateral (or route separation), departure standards, crossing standards and combined-displacements standards. Keep standards separate at this stage (for example, do not mix radar with wake vortex standards). The same separation standards are to apply to all ATC facilities.
2. Determine radar surveillance need (including redundancy and Mode S), establish system-wide access to shared radar data (initially for service providers, then airlines, etc). For efficiency, identify all radars surplus to requirements and decommission. Add as soon as possible ADS-B surveillance (for extra information when available, including intent).

3. The future is management by trajectory, so review all "blocks" of airspace, especially military and high level prohibited and restricted areas, for appropriateness of dimensions and to create transit corridors. (This review to be repeated regularly to ensure appropriateness of airspace allocations.)
4. Create "direct routes" for operations above Flight Level (FL) 110 (or 11,000 feet above ground level), building in the radar route separation standards (from step 1) and making use of transit corridors (from step 3). Do not consider facility and sector boundaries when creating routes. Determine the strategic (preferred) and tactical separation methods to be used as part of route creation, including the handling of crossing routes. The routes must not be created ignoring the fact that restricted-access airspace volumes exist. If there is frequent use of a restricted airspace (for example, a military restricted area), the route must avoid it (for example by using a transit corridor). For all other (infrequent) defined restricted airspace volumes, define routes around the airspace for when the airspace is active (defined diversions) that can be used for strategic separation.
5. For high density routes, define parallel routes that permit strategic separation of opposite direction traffic or same direction traffic with different speeds. Consider route speed limits (minimum and maximum).
6. Define vertical requirements for routes (for strategic separation with other routes, especially during climb and descent).
7. For safety, create off-level "standards" for routes (small vertical displacement).
8. Design standard departures and arrival routes for operations below FL110, considering environmental requirements and separation (especially strategic) requirements. Consider defined speed requirements for last stages of arrival routes (for each segment, perhaps even in ground speed not indicated airspeed).
9. Review facility boundaries to suit routes promulgated. Ensure adjacent facilities can exchange airspace at least at boundaries (to handle weather diversions, etc).
10. Review sectors within facilities minimising vertical boundaries.

This does not create the ATM system of the future – but it does address a few of the problems currently experienced and will prepare the ATM system for the bigger changes required to implement other aspects of the ICAO Concept.

Note that this is not a technological solution – in the sense that the solution is simply using what is already available today.

This example demonstrates the very big test of the commitment of the ATM community to achieve the changes needed. It does not affect states sovereign airspace or rights – and their laws and regulations still apply. The major change is for the service provider whose area of responsibility may no longer be precisely aligned with state boundaries - but this is just requiring service providers to act like an international business (like the airlines). It is still up to the states to decide whether the regulator can accept the action of the "regulator of location of business" of the service provider as sufficient or whether separate action is required. The military will not necessarily have less airspace, as trade-offs are done – but the selection of airspace for discretionary military activities will have additional requirements (in addition to the requirements for transit corridors).

The airspace users should find a significant increase in availability, capacity and flexibility. Although this has not implemented 4-d trajectories, many direct routes are available including through previously blocked airspace. Some restrictions are placed on trajectories to ensure capacity, but this is an acceptable trade-off to the problems of delays and lack of capacity. It creates an environment in which commitments can be made to further improve the ATM system.

Example 2 - Global Upper Airspace

Whereas the previous example was states working together, this example provides a global approach to solving some of the problems.

Global ATM has many inconsistencies and problems. One approach to making a change on a global scale is a commitment to establishing a global upper airspace with agreed standards for ATM and a commitment of service providers to work together to achieve the best results.

Pick a level, for example FL200. All operations above the level would be considered as part of global traffic (even if only on a domestic flight).

One early standard for this upper airspace may be that any datalink capable aircraft will always be in datalink communication with a service provider. Note this does not mean that there will always be the expense of data exchanges, but the capability of datalink communication will be available, even if only for emergency communication. It also does not mean only one service provider for this airspace. It does mean that agreements will be put in place that an aircraft can send a datalink message to the controller responsible for the flight. For example, it seems unreasonable that the passengers can be talking on satellite phones while the pilot has been trying for the last 20 minutes to request a level change via HF – or even just to give a routine position report. In the days when HF was more common, it was very common for service providers to relay messages that they overheard. Service providers should be able to relay to other service providers messages received via datalink (or other forms of communication).

Another issue for upper airspace may be a traffic information service, or assistance with strategic de-confliction of known traffic prior to entry to a particular airspace, especially in Traffic Information Broadcast by Aircraft (TIBA) airspace. Once again this is not to deny the rights of the state, but a cooperative approach to sharing information between as many of the affected members of the ATM community as possible. This is a serious problem when ground infrastructure is not meeting a minimum standard and it is inappropriate to leave it to the airspace users to sort out as best that they can when assistance can be provided.

Once the high priority safety items have been addressed, interoperability standards for global upper airspace would be developed. Of course upper airspace does not exist by itself and is affected by the choices made for ground systems for airspace below FL200. However in a cooperative data sharing environment, cost effective solutions should be able to be implemented. For example, with appropriate preparation it may be possible to define and implement 4-d trajectories in the upper airspace long before it would be practical to implement 4-d trajectories for lower airspace.

Global electronic surveillance of operations above FL200 is also a possibility.

The intent here is not to prescribe a particular solution in upper airspace, but to indicate that such a division might have practical and beneficial outcomes.

Appendix 16 – "It will never happen..."

At one time it was hard to believe that an airline flight crew would not contain a flight engineer – however automation has taken over that task.

At one time it was hard to believe that the government would not support a national airline carrier that was failing – but this has happened.

At one time it has hard to believe that a passenger aircraft would be without physical flight controls, but now fly-by-wire has been successfully implemented.

There are many more examples.

Just because promised changes have not yet occurred does not mean they will never occur.

"People who say it can't be done should get right out of the way of those who are already doing it!" – Iris Caskey

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