ATM depends on the exchange of information

Innovative air traffic management (ATM) concepts, based on new decision-making procedures and a redistribution of responsibilities between pilot and controller, are currently being defined and demonstrated. These innovative ATM concepts depend on the timely, efficient and secure exchange of information between all entities involved in a flight; including aircraft, air traffic control (ATC) units, airline operations centres (AOCs) and airports.

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The Swedish civil aviation administration (Luftfartsverket), the air navigation service provider in Sweden, has taken important steps towards the operational implementation of a new infrastructure for digital communications. This infrastructure supports the ICAO Global ATM Concept endorsed by the 11th Air Navigation Conference and the European ATM Programme (EATMP), serving as an essential enabler of the new ATM system.

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The new ATM system

The ICAO Global ATM Concept provides a framework for the development of the new ATM system. Numerous activities are ongoing, particularly in Europe, in order to further define the details of such a system. This will ultimately result in a clear set of requirements, supporting tools, functions and operational procedures, together with an adapted legal framework. The new ATM system will be implemented step by step in an incremental way, as “big bangs” are not feasible in aviation.

The principle of “start small but think big” has to be applied if expectations concerning safety, efficiency, capacity, reduced costs and reduced impact on the environment are to be met. Early implementation has to be expandable and sup-

port more than just initial functions. Dead ends should be avoided as they might jeopardise the whole process.

A key element in the new ATM system is the reliance on distributed responsibility for decision-making. It is, for example, expected that controller workload will be significantly reduced if separation responsibility can be delegated to pilots. Implementing Airborne Separation Assistance (ASA) applications, including 4D-trajectory (intent) broadcast, will provide pilots with increased situational awareness, creating the fundamental support tool that will make it possible for pilots to take over spacing and separation tasks.

Availability of accurate and sufficient information in a timely manner is a prerequisite for the change in roles. Information will be exchanged by digital communications using data links, while traditional voice communication will be retained mainly for non-routine messages and emergency situations.

It is expected that the new ATM system will be more focused on management and planning, resulting in a smoother, more flexible and optimised flow of traffic in accordance with aircraft performance characteristics, leading to reduced costs and lower impact on the environment. The accuracy of planning is highly dependent on what data is available. Data used in traditional systems, providing information on where aircraft have been (radar data) and flight plan data, is not sufficient. Making intent data from aircraft on-board systems available to ground systems (and to other aircraft in the vicinity) opens up new dimensions for very precise predictions and a reliable understanding of how aircraft will manoeuvre.

Communication capabilities

Delegation of responsibility to pilots for maintaining separation requires surveillance data to be available in the cockpit, i.e. it is necessary to provide an aircraft-to-aircraft broadcast data link providing position and intent information. Where pilots are expected to resolve conflicts by themselves, a direct, efficient and secure point-to-point data link connectivity between aircraft will also be required that can operate without the involvement of a ground infrastructure (i.e. to support operations in continental areas as well as vast areas without a ground infrastructure). Traditional air-to-ground data link connectivity will be required to keep ATC and AOC in the loop.

Secure communications

Whilst the new ATM system provides for increased safety and security, it also opens up a new threat to the underlying data links themselves. Therefore, applications such as Controller Pilot Data Link Communications (CPDLC), digital voice, Collaborative Decision Making (CDM), Automatic Dependent Surveillance – Broadcast (ADS-B) and broadcast of flight information require data link security mechanisms to provide services such as user authentication, integrity, confidentiality and replay prevention.

Security mechanisms will be required in both the air-ground and ground-ground infrastructure. However, the key concern in aviation is the air/ground media where the application of industry solutions will be harder. The real-time nature of aviation applications, combined with the limited bandwidth available on air-ground data links and physical limitations within airframes, severely restricts the security solutions possible.

The implication is that aviation needs to look at the properties of air-ground data links and available information when determining how to best achieve the required level of data link security. For example, the exchange of data between the traditionally independent domains of Communications, Navigation and Surveillance (CNS) suggests the possibility of using reported position data in authentication mechanisms. However, the use of ADS-B data raises the issue that the position information itself may be spoofed. The reported position data should therefore be compared with measurements of the time it took for the data to be transmitted from the sender to the receiver, thus providing independent verification of the position information used to determine identity.

Reporting position and intent data and time measurements are inherent in an ADS-B system like VDL Mode 4, in which the receiver uses time measurements for the independent verification of reported positions.

ATM depends on the exchange of information (cont'd)

ATM depends on communication elements in CNS

The first steps towards understanding the requirements mentioned and transforming these into a technical system approach were taken some 15 years ago. At that time, ADS-B did not exist and Global Navigation Satellite System (GNSS) was in its early stages. Luftfartsverket found, after consultations with the operators, ATM specialists and international organisations, that all technical domains (CNS) in CNS/ATM contained communication elements that would be supported by digital communications via data links.

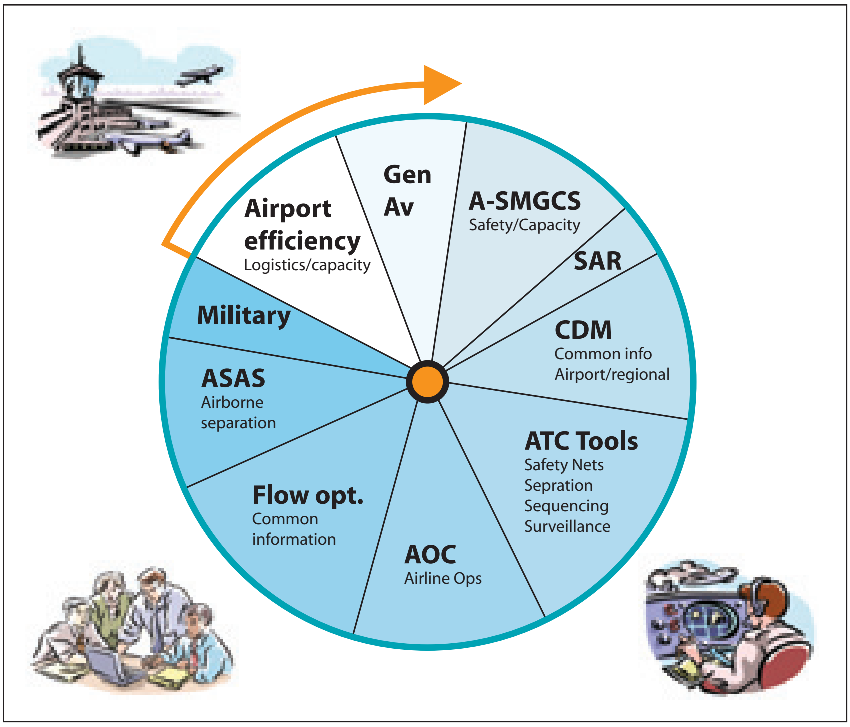
Consequently, Luftfartsverket decided to support the development of a CNS data link "toolbox" optimised for cooperative ATM applications. The critical requirements were that the "communication toolbox" should:

- support all phases of flight;
- include Communication, Navigation and Surveillance (CNS) elements;
- be applicable to all types of users;
- be adaptable in support of global implementation.

Issues like expandability, safety critical, redundancy, security and fail-safe became paramount after involving aircraft system and certification experts. Fifteen years on, this has led to global standards for VDL Mode 4 being available for use by aviation when implementing the new ATM system.

The protocols in VDL Mode 4 with the unique "self-organising mechanism" support all the communication capabilities required and all the data elements needed can be accommodated. It should be noted that the major effort on developing new ATM functions, including the communication system, is devoted to applications and protocols. Although VDL Mode 4 operates in the VHF band, the physical layer could easily be changed so that services could be provided in any other frequency band that is available for aviation use with no or only minor changes to the application/protocol levels in the installations on board aircraft and in the ATM systems on the ground.

Implementations in Sweden



A wide range of applications and areas was assessed prior to the introduction of VDL Mode 4 in order to secure a positive business case. The "user wheel" approach was adopted in the early 1990s as a model for identifying the common elements for various user groups and applications. In the centre lies a set of communication elements that are common to all users, such as common time reference (UTC), unique position and mechanisms for the management of the cellular communications.

The alternative is the "piecemeal" approach where one application, or set of applications, is related to a specific technology such as VDL Mode 2 for AOC and initial ATC services, 1090ES for initial ADS-B, Multilateration for surveillance on airports and GBAS/VDB for GNSS augmentation. This approach was discarded early as the fragmentation was found to be too costly for service providers as well as users. The technical limitations will most likely result in ongoing extensive implementations being unable to support the envisaged services in the new ATM system and unable to deliver the expected benefits. Furthermore, unique solutions for security mechanisms have to be found for each system.

Luftfartsverket's current plans call for a stepwise introduction of VDL Mode 4 in various areas, starting with airport efficiency (A-SMGCS), General Aviation (GA) and use of ADS-B in non-radar areas. The introduction of both systems and applications will allow a logical build-up of experience and understanding of the critical issues in using advanced data link communications. A network of ground transceivers, covering the main airports and airspace in Sweden, will be in place in mid-2005, providing the basis for subsequent expansion of services. In Kiruna, the northernmost airport in Sweden situated above the Arctic Circle will be the first to introduce "radar-like" services, using ADS-B on a daily basis. At Stockholm/Arlanda airport, VDL Mode 4 is used both for optimising airport logistics and for forming an integrated part of the A-SMGCS system. The investment in infrastructure is being shared between the airport and air navigation service provider, thus providing a positive business case for Luftfartsverket.

A programme for GA was launched in 2003 in order to include low-end and non-commercial users. The purpose is to ensure that ATC and GA users can benefit from advanced data communications at a reasonable cost. The programme includes broadcasting of simple Flight Information.

In 2004 a CPDLC programme for Sweden was started, designed to provide communications services such as clearance delivery and flight information.

For both large commercial aircraft and low-end users, VDL Mode 4 will include a multimode radio providing both voice and data communication capabilities. The concept of multimode radios will reduce the number of communication equipment sets on board aircraft and secure backwards compatibility. The current development includes the introduction of security mechanisms in the network and independent verification of reported position data by range measurements in the receiving units.

Validation of the various applications is mostly performed in close collaboration with EUROCONTROL.

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Conclusion

The ICAO Global ATM Concept is being implemented through various activities worldwide. The approach taken in Sweden is an incremental introduction of new ATM functions. It is essential to ensure that the selected solutions are expandable and able to form an element of the final ATM system. The principle of "start small but think big" is being applied.

The new ATM system must be based on the efficient and secure exchange of requisite data in a timely manner. Data need to be exchanged between aircraft as well as between aircraft and ATC and AOC on the ground. Mixing broadcast distribution and point-to-point exchange of data is a way of overcoming spectrum and aircraft architecture limitations and still ensuring security, integrity and confidentiality.

VDL Mode 4 is the only system standardised by aviation that supports all identified communications requirements. Luftfartsverket has taken the first steps towards the operational use of new ATM functions supported by the integrated CNS functions in the VDL Mode 4 system. ■