TECHNICAL REPORT

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TITLE : **THE MORE AUTONOMOUS - AIRCRAFT IN THE FUTURE AIR TRAFFIC MANAGEMENT SYSTEM**

ATM KEY CONCEPTS AND REQUIREMENTS

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Record of changes

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1 Introduction

1.1 Background

1.1.1 The civil avionics market is in the early stages of a major revolution, which is being driven by the inexorable growth of civil air traffic (between 5% and 8% a year). This growth is pushing the current Air Traffic Management (ATM) systems to breaking point. Within Europe, the situation can be characterised by long delays for passengers, inefficient routeing for operators and unacceptable stress for controllers.

1.1.2 Programmes and trials are being carried out in Europe, the USA and the Pacific to alleviate the problems. One key to these activities is the development of a concept of more capable aircraft which will be substantially less dependant on ground based facilities (as outlined in the ATM 2000+ Strategy and Eurocontrol OCD documents). This in turn will lead to a dramatic increase in the functionality of civil avionic systems, particularly in the areas of navigation, communication and flight management (CNS/ATM).

1.1.3 Both the More Autonomous Aircraft in the Future ATM System (MA-AFAS), and the Aircraft in the Future ATM System (AFAS) programmes address the requirements of Key Action 4 New Perspective in Aeronautics, Technology Platform 4.

1.1.4 Building on the Framework 4 AFMS and AATMS projects, the MA-AFAS programme aims to transform European research results into practical operational ATM procedures with the potential to radically improve the European ATM scenario in the near term (from 2005 onwards). By selecting and validating key airborne elements of Communications, Navigation and Surveillance (CNS), and defining their economic benefits and certification requirements, the research will enable more autonomous aircraft operation in the European ATM system.

1.1.5 Specific areas to be addressed by MA-AFAS include:

- Evaluation of airborne 4 Dimensional (4D) flight path generation for integration with ground based flight planning
- Validation of Global Navigation Satellite System (GNSS) (with ground and space based augmentation) procedures for approach using 4D flight path control
- Integration of airborne taxiway map and data-linked clearances
- Validation of Automatic Dependent Surveillance – Broadcast (ADS-B) with Cockpit Display of Traffic Information (CDTI) and Airborne Separation Assurance (ASAS) algorithms.

1.1.6 AFAS will implement as a baseline the following functionalities in the 3 CNS domains covering:

- Data Link services
  - Data-link Initiation Capability (DLIC)
  - Clearance and Information Communication (CIC) based on Controller Pilot Data-link Communication (CPDLC)

- ATC Communication Management (ACM) providing automated assistance to the aircrew for conducting the transfer of ATC communications (voice and data-link) between current and next ATC centre or for initiation connection with ATC controller.

- Departure Clearance (DCL) providing automated assistance to the aircrew for requesting and receiving clearance for departure.

    - Air Traffic Information Service (ATIS) allowing up-linking of operational flight information for departure, approach and landing phases.

    - Flight Plan Consistency (FLIPCY) allowing automated cross referencing of aircraft and ATC flight plans

    - Dynamic Route Availability (DYNAV) allowing the up-linking of availability of new routes.

- Navigation:

    - Navigation functions RNP related: alerts generation when position accuracy or integrity is insufficient for the current requirements (RNP), sensors management, data blending for best position

    - Flight Plan Management: flight plans down-linking

    - 4D Guidance: lateral and vertical guidance providing paths to follow lateral and vertical trajectories, Required Time of Arrival (RTA) function

    - Precision approach landing CAT III capability with MLS

    - Precision approach landing CAT I capability with DGNSS

    - MMR multi-sensor management for landing (DGNSS, ILS, MLS)

1.2 Purpose of Document

1.2.1 Whilst the strategic requirements of MA-AFAS (and AFAS) can be quantified (as summarised in section 1.1 above), further development of these requirements is needed before the ATM Operational Concept, (and later the Avionics Package functionality) can be chosen. This document is intended to be the first stage in the requirements capture process.

1.2.2 Work Package 1.1 (in collaboration with the AFAS Consortium), has carried out a review of European and US projects, programmes and strategies that were considered relevant to both MA-AFAS and/or AFAS. This document summarises these reviews, and attempts to draw out the “key concepts” of potential relevance to MA-AFAS and AFAS that were identified within the projects, along with any supporting requirements, standards or other relevant information.

1.2.3 It is intended that this document will be reviewed by the MA-AFAS and AFAS consortiums in conjunction with the initial draft Candidate Operational Concepts (from MA-AFAS Work Package 1.2.1) as the first stage of the process for selecting a common Operational Concept to be pursued by both projects.

1.3 Review of ATM Projects

1.3.1 The projects included in the review process were proposed by the project partners and were intended to cover all relevant fields of ATM research. To ensure a “global” view was taken, selected North American projects were reviewed, in addition to European projects funded by the European Commission, Eurocontrol and European States.

1.3.2 Where possible, the reviewing task for each project was allocated to a partner that had participated in the project, in order to obtain the best possible knowledge and understanding of the project results and achievements. Unfortunately, due to the start time for AFAS being one month later than for MA-AFAS, and with very tight timescales to be met, it was not always possible to allocate projects in this optimum way.

1.3.3 The output from each review was a brief description of the project objectives, a description of the methods employed to achieve those objectives, a summary of the main results obtained and conclusions reached, and finally the “key concepts and requirements” identified within the project. These reviews can be found in Annex A, in their entirety, although Section 2 summarises the most relevant information.

1.4 Definition of “Key Concepts”

1.4.1 For the purpose of this review, a “key concept” is defined as “*a <u>fundamental</u> concept of aircraft operation within an advanced ATM environment for which requirements can be specified and technical enablers identified”.*

1.4.2 Whilst most of these concepts can stand in their own right, some can also act as enablers for other key concepts (an example would be Dependent Surveillance, where the realisation of such a concept is an important technical enabler for the Delegation of Separation Assurance).

2 Project Summaries

2.1 3FMS – Free Flight, Flight Management System

2.1.1 Key Concepts and requirements derived from 3FMS

The 3FMS project explores the concept of Free Flight as applied to three types of airspace. These three types are:

- Free Flight Airspace (FFAS)
- Managed Airspace (MAS)
- Special Use Airspace (SUA)

The project also addresses, through simulation, the use of the system during the taxi phase. It sought to discover if 3FMS could reduce taxi time, increase situation awareness and reduce pilot workload.

The concepts/enablers being used in 3FMS are FMS, conflict detection and resolution, priority determination, CDTI, CPDLC, ADS-B, TIS-B and taxi management.

2.2 AATMS – Advanced Air Traffic Management System

2.2.1 Key Concepts and requirements derived from AATMS

AATMS addressed the area of advanced flight management systems for operation in a CNS/ATM based environment. The objective was to demonstrate the Flight Management System (FMS) with a range of CNS functions during live trials. Using an Aeronautical Telecommunications Network (ATN) based data link, Airline Operational Control (AOC) functions were developed and also demonstrated.

The FMS employed full 4D functionality with GNSS based navigation for compliance with the RNP concept. The data link system enabled ADS, meteo, AOC and 4D negotiation over VHF and satcom sub-networks via a prototype Communications Management Unit (CMU).

2.3 AFMS – Advanced Flight Management System

2.3.1 Key Concepts and requirements derived from AFMS

The AFMS project concentrated on the development and evaluation of an Advanced Flight Management System capable of operating in the predicted environment of a CNS/ATM scenario. Functionality of both a short term and medium term FMS was designed and implemented. AFMS validated the following concepts: Air/Ground communication over data links.

The tools used were ADS (to ARINC 745 –2), ATN, airborne HMI, CPDLC/AOCDLC, 4D trajectory generation, negotiation and navigation.

2.4 ARAMIS – Advanced Runway Arrivals Management to Improve Safety and efficiency

2.4.1 Key Concepts and requirements derived from ARAMIS

ARAMIS addressed problems with runway capacity during the arrivals phase. It used increased knowledge of Aircraft State and performance to predict aircraft movements more accurately and thus reduce approach separation.

The project, although using aircraft derived data, was aimed at providing controller aids. The concepts investigated were the use of data links to gain knowledge of the Aircraft State, high fidelity performance models and HMI.

2.5 ATM Strategy for 2000+

2.5.1 Key Concepts and requirements derived from ATM2000+

The ATM Strategy for 2000+ presents, by phase of flight and timescale, the development strategy of a future ATM system. Beyond 2005 it can be seen that aircraft will increasingly rely on data links and 4D-flight management. Increased situation awareness will be available through the use of ASAS (with delegation of separation assurance in some defined circumstances) and other cockpit systems.

Management of the flight will be enabled through the use of Collaborative Decision-Making (CDM) as AOC are involved in the planning process. Airport surface movement would also play an important part in an automated system.

2.6 AVENUE – an ATM Validation Environment for Use towards EATMS

2.6.1 Key Concepts and requirements derived from Avenue

Avenue is a project designed to provide an open, flexible platform for developing and supporting future European ATM systems. As such there are no key concepts that relate to MA-AFAS or AFAS directly. However, its use within MA-AFAS / AFAS will allow validation of the concepts developed.

2.7 Capstone (FAA Alaska Region)

2.7.1 Key Concepts and requirements derived from Capstone

The Capstone programme was created to address Alaska’s high accident rate for small aircraft through installation of new equipment (GPS-based avionics and datalink communication suites) in commercial aircraft and the provision of compatible ground systems, equipment and services. The principal objective of the Capstone Program is to improve the pilot’s situational awareness of the flight environment.

Some Capstone equipped aircraft and the ground system infrastructure were used beginning January 2000 to validate three of the nine high priority Free Flight operational enhancements as identified by the Safe Flight 21 programme:

- FIS for SUA, Weather, Windshear, NOTAMS, Pilot Reports
- Controlled Flight & Terrain Avoidance through Graphical Position display
- Enhanced See and Avoid

2.8 CASCADE – Contribution to the Assessment of Common ATM Development in Europe

2.8.1 Key Concepts and requirements derived from CASCADE

CASCADE aims to identify needs, propose solutions and select candidate facilities for ATM systems in Europe. Its role is to survey and maintain a database of existing validation facilities in Europe.

As such there are no key concepts that relate to MA-AFAS or AFAS.

2.9 CDM – Collaborative Decision Making

2.9.1 Key Concepts and requirements derived from CDM

The CDM project identifies potential applications of CDM based on flight phase, from gate to gate, and within the context of the European ATM System (EATMS). CDM attempted to understand how the operation of today's ATM system could be improved by sharing information and allowing the appropriate expert in the system to make the decisions. CDM identified 22 areas of potential benefit. The use of CDM applications, as outlined in ATM2000+, is predicted to play an increasing role in future ATM systems. As such CDM is seen as a key concept in its own right, drawing on resources from information systems both airborne and ground based.

The CDM process relies upon the information gathered and will require accurate aircraft information, air/ground, air/air data links, links to taxi management systems, taxi and flight profile prediction, HMI, multi-sector planning, 4D trajectory negotiation capabilities and links to AOC and other knowledge based systems.

2.10 DADI – Datalinking of Aircraft Derived Information

2.10.1 Key Concepts and requirements derived from DADI

The DADI project explored the general concept of using aircraft derived information, passed over a data link, to fulfil the requirements of ground based users. It investigated the use of radar based and beyond line of sight data links to increase ATC knowledge of the Aircraft State to reduce controller workload and thus improve control of those aircraft.

2.11 EOLIA – European Pre-Operational data link Applications

2.11.1 Key Concepts and requirements derived from EOLIA

EOLIA's objective is to develop and evaluate a set of ATN compliant, Air Traffic Control (ATC) data link services to improve air traffic management and reduce controller and pilot workload. The key concepts of relevance to MA-AFAS are the use of air/ground data links to replace some of the current routine voice communications. The following data link services were selected: DLIC, ACL, ACM, APR, DSC and FLIPCY. The system requires the use of an air/ground data link, ATN and HMI.

2.12 FACTOR – Development of Functional Concepts from the EATMS Operational Requirements

2.12.1 Key Concepts and requirements derived from FACTOR

The objective of FACTOR is to define assessment criteria and develop an assessment methodology to assess functional concepts. As such there are no key concepts that relate to MA-AFAS or AFAS.

2.13 FARAWAY – The fusion of radar and ADS data through two way data link

2.13.1 Key Concepts and requirements derived from FARAWAY

The FARAWAY project aims to develop and demonstrate new operational procedures based on the fusion of ground based radar and aircraft derived ADS data through the use of a two way data link. Applications being investigated as part of the project are as follows: ADS-B to enhance surveillance, augmented GNSS for improved navigation performance, fusion of surveillance data from PSR/SSR and ADS-B, TIS-B data presented on the CDTI, aircraft and airborne situation awareness through improved information and HMI.

2.14 FREER FLIGHT – Free-er Flight

2.14.1 Key Concepts and requirements derived from FREER Flight

This project addresses the delegation of separation assurance to the cockpit in the time frames 2005 to 2015 and 2015 and beyond. Its main objective is to increase airspace capacity by mainly reducing controller workload. The iterative approach of starting with limited delegation and moving towards more advanced full delegation, is intended to allow for an evolutionary introduction. The concept is applied in three types of airspace: Free Flight Airspace, Managed Airspace and Special Use Airspace. The system is reliant on ADS-B, TIS-B and CDTI to allow conflict detection and resolution depending upon the level of delegation.

2.15 ISAWARE – Improvement of Situation Awareness

2.15.1 Key Concepts and requirements derived from ISAWARE

The main object of ISAWARE is to improve flight safety by providing the pilot with a complete predictive situation awareness during all phases of flight. One axis of the research is the integrated processing of the outputs from various safety items such as ACAS/TCAS, GCAS/GPWS, Weather Radar, Wind shear & wake vortex detector etc. taking into account other information such as the flight plan, ADS-B and other uplinked messages. The second axis of research is the development of a synthetic display to enhance the cockpit Human Machine Interface. Since ISAWARE addresses all phases of flight, including Enroute, landing, taxi and takeoff, head down displays like EFIS (Electronic Flight Instrument System) and head-up displays will be considered.

2.16 M-ADS – Modified Automatic Dependant Surveillance

2.16.1 Key Concepts and requirements derived from M-ADS

The objective of M-ADS is to improve the safety of offshore Norwegian helicopter operations through the use of improved datalink based surveillance. The helicopters operate outside radar coverage using Context Management log on and ADS-C established over an ATN compliant satellite data link. Support is also included for HF and VHF sub-networks.

2.17 NUP – Northern European ADS-B Network Update Programme

2.17.1 Key Concepts and requirements derived from NUP

NUP is a follow-on project from the NEAN and NEAP projects. Split into 2 phases its main objective is to update the use of VDL Mode 4 in air/ground data link ADS-B applications, in support of new ATM concepts. Work is to focus on TIS-B, in conjunction with FARAWAY and the Eurocontrol ADS programme. NUP addresses issues such as ASAS and pilot traffic situation awareness.

2.18 ODIAC – Airborne Situation Awareness (AIRSAW) Task Force

2.18.1 Key Concepts and requirements derived from ODIAC/AIRSAW-TF.

ODIAC/AIRSAW-TF presents a possible strategy for implementation of the AIRSAW concept, based on the EATMS OCD and ATM 2000+ Strategy. It will be one of the enablers for the transfer of separation assurance tasks to the flight crew. ODIAC/AIRSAW-TF first predicts a limited transfer of responsibility of separation assurance from the controller to the pilot. From 2015, extended transfer of responsibility is introduced in free flight airspace. The transfer of responsibility is addressed on four levels, these being Strategic, Tactical and Operational, Technical and Safety.

2.19 Ohio Valley ADS-B (Cargo Airlines Association)

2.19.1 Key Concepts and requirements derived from the Ohio Valley ADS-B programme.

The Cargo Airlines Association ADS-B programme aims to develop an Enhanced Collision Avoidance System based on ADS-B technology to achieve an improved separation tool. The three phases of the programme can be summarised as follows:

- ADS-B based CDTI – enhanced visual acquisition of traffic for see and avoid.
- Conflict detection functionality
- Provision of resolution advisories, resulting in full conflict detection and resolution functionality

The first operational evaluation in July 1999 centred on ADS-B applications, the CDTI and flight procedures. The results of the operational evaluation should validate the CDTI concepts of RTCA SC-186.

2.20 PETAL II – Preliminary Eurocontrol Test of Air/Ground Data link

2.20.1 Key Concepts and requirements derived from PETAL II

PETAL II, a continuation of PETAL, focuses on the validation of the operational concept, operational requirements and operational procedures for the EATCHIP III air/ground data link. The project implements the following data link services: CM/DLIC, ADS/FLIPCY, ADS/CAP, CPDLC/ACM, CPDLC/ACL and CPDLC/AMC. The NEAN VDL mode 4 prototype is to be used for the ADS-B service.

PETAL II does not advocate the use of the data link for critical communications and does not concern the tactical separation of aircraft. The project implements a SARPs compliant ATN, and ODIAC compliant services.

2.21 PHARE – Programme for Harmonised Air Traffic Management Research in Eurocontrol

2.21.1 Key Concepts and requirements derived from PHARE

The PHARE programme demonstrated the concepts of strategic 4D-trajectory generation, negotiation, clearances and navigation in three demonstration phases. The first concentrated on Enroute operation, the second covered TMA arrivals and the third covered all flight phases from takeoff to touchdown. Data link was employed to transfer information between air and ground. This enabled 4D trajectories to be negotiated and aircraft position to be reported using ADS-C.

2.22 ProATN – Prototype Aeronautical Telecommunication Network

2.22.1 Key Concepts and requirements derived from ProATN

ProATN is the identification, definition, development, integration and development of a SARPs CNS/ATM 1 compliant ATN. Through co-ordination with the EOLIA project, ProATN will demonstrate operation of the ATN via the EOLIA services. The use of the ProATN data link will expand to PETALII, FAA CPDLC and M-ADS programmes.

2.23 RHEA – Role of the Human in the Evolution of ATM Systems

2.23.1 Key Concepts and requirements derived from RHEA

RHEA identifies the risk that unsuitable automatic systems, for the controller, could be implemented in the future. The project attempts to reduce these risks by providing a framework of modelled assessment by which the chances of success may be predicted. All of the concepts in preparation for MA-AFAS and AFAS will involve various degrees of automation for both the pilot and controller. As these concepts are developed, the role of the human must be given due consideration.

2.24 Safe Flight 21 (FAA)

2.24.1 Key Concepts and requirements derived from Safe Flight 21

Safe Flight 21 aims to evaluate enhanced capabilities and expedite decisions for Free Flight, based on evolving CNS Technologies, including GPS, ADS-B, FIS and TIS-B, and their integration with enhanced pilot and controller information displays.

Nine high-level operational enhancements have been identified, along with the potential benefits, examples of risks and issues to be resolved. Under the auspices of the Safe Flight 21 office there are two major ADS-B demonstration projects in the United States, the Ohio Valley demonstration and the Alaska Capstone programme, both described elsewhere in this document

2.25 RTCA SC-186 (Special Committee 186) Activities

2.25.1 Key Concepts and requirements derived from RTCA SC-186

SC-186 is a special committee, established in 1995, entitled Automatic Dependant Surveillance - Broadcast. Its task is to develop operational requirements and minimum performance standards for ADS-B. The committee has produced the following documents: RTCA/DO-242 - Minimum Aviation System Performance Standards for ADS-B, RTCA/DO-243 - Guidance for Initial Implementation of CDTI, RTCA/DO-249 - Development and Implementation Planning Guide for ADS-B Applications.

Further documents are in preparation for Operational Concepts for CDTI Initial Applications, MOPS for CDTI, MOPS for ASSAP and Concept of Operations for Aircraft based traffic conflict detection and resolution. Operational concepts include Enhanced Visual Acquisition, Enhanced Visual Approach, In-Trail Climbs and Descent in Non-radar Airspace, In-Trail Climbs and Descent to Co-Altitude in Non-radar Airspace. The requirements for the concepts include ADS-B, TIS-B and TCAS.

2.26 TELSACS – Telematics for Safety Critical Systems

2.26.1 Key Concepts and requirements derived from TELSACS

TELSACS identifies the use of data links to exchange safety critical conflict information between air and ground so that controllers and pilots are presented with the same conflict information, thus harmonising the conflict resolution. HMI issues and communications aspects have been validated through the use of ADS-B, ACAS and STCA.

2.27 TORCH – Technical, Economical and Operational Assessment of an ATM Concept Achievable from the Year 2005

2.27.1 Key Concepts and requirements derived from TORCH

The TORCH objective is the delivery of a viable, consolidated operational concept for the year 2005 onwards. Based on the EATMS OCD and ATM 2000+ strategy TORCH contributes to the 7 main objectives included in these programmes. However, through prioritisation, capacity, safety and economics have been chosen as the main objectives.

The TORCH operational concept proposes a layered planning process, based on a more flexible use of the airspace and with a greater involvement of the ATM actors through the optimisation of the available resources instead of constraining demand. These concepts, consisting of 18 elements, are grouped into 7 clusters. The clusters comprise all the phases of flight and all the actors involved in the ATM process.

It is intended that the candidate operational concepts to be considered for the MA-AFAS and AFAS programmes will relate to the TORCH operational concept.

3 Key Concepts and Requirements Identified

3.1 Introduction

3.1.1 As can be seen from section 2, many of the key concepts identified in the project reviews were found to be common. The following section attempts to pull these concepts together into a single coherent table, identifying the relevant key requirements, technical enablers and applicable standards where possible. It is intended that this table will cover the key concepts and requirements for both MA-AFAS and AFAS.

3.1.2 As this document is intended to be reviewed by the MA-AFAS and AFAS consortiums, in conjunction with the initial draft Candidate Operational Concepts (from MA-AFAS Work Package 1.2.1), and the initial draft Candidate Operational Concepts have been decomposed following the TORCH classification, the table also includes references to the relevant TORCH elements.

3.2 Table of Key Concepts and Requirements

Key Concept	Description of Concept	Relevant TORCH Elements	Key Requirements	Technical Enablers
KC1 Advanced Surface Movement	An advanced surface movement guidance and control system providing controllers and pilots with improved situational awareness and taxi clearances via datalink.	E7, E8, E10, E13, E18	• ADS-B Service • TIS-B Service • Cockpit HMI capability - Taxi-map capability • Taxi clearances Service • Taxi advisories Service • Taxi guidance Service	• A/A Datalink • A/G Datalink - CPDLC - Other D/L • GNSS
KC2 Arrivals / Departure Management	Flexible TMA / arrival / departure / precision approach paths providing reduced noise and more efficient operation. Fixed arrival/departure routes (either published or uplinked via datalink) with a single RTA or full 4D arrival/departure routes	E6, E18	• Precision approach capability • RNAV / RNPx capability	• 4D FMS • A/G Datalink - CPDLC • GNSS • SBAS/GBAS
KC3 Dependant Surveillance	The provision of surveillance information in airspace with no radar coverage. The information is derived directly from the aircraft systems.	E7, E8, E18	• ADS (or ADS-B) Service	• FMS, ADC, CMU, GNSS etc • Datalink - DAP

Key Concept	Description of Concept	Relevant TORCH Elements	Key Requirements	Technical Enablers
KC4 A/G ATM Datalink Services	Enhancement of air / ground communications also providing strategic operational capabilities, but voice retained for tactical control.	E4, E5, E6, E7, E8, E10, E11, E13, E16, E18	• ATN CNS ATM Pkg. 1 capability • Cockpit HMI capability • DLIC Service • ACM Service • CIC Service • DSC Service • DYNAV Service • FLIPCY Service • FIS Service • SAP Service (Measured met.) • CAP Service • D-ATIS Service • (Other ATS services) • AOC Services	• A/G Datalink - VDL mode 2 - VDL mode 3 - VDL mode 4 - AMSS - Mode-S - UAT - ACARS • CMU • TIS
KC5 4-D Strategic Clearances	Strategic ATM operation through the use of negotiated full 4-D trajectories and clearances or 3D trajectories with single (or multiple) RTAs (4D Strategic Clearances could be seen as a “real-time” component of CDM)	E4, E5, E6, E10, E11, E13, E18	• 4-D trajectory generation capability • 4-D trajectory negotiation capability • 4-D guidance and control capability • D-FIS Services (Meteo data in cockpit) • Cockpit HMI capability	• 4-D FMS • CMU • GNSS • A/G Datalink - CPDLC - Other D/L • Navigational database

Key Concept	Description of Concept	Relevant TORCH Elements	Key Requirements	Technical Enablers
KC6 Collaborative Decision Making	Links ATC, AOC and aircraft together to enable decisions on routing, sequencing etc. to be made in a collaborative way.	E4, E5, E6, E10, E11, E13, E18	• Cockpit HMI capability • AOC A/G Datalink Services	• 4-D FMS • A/G Datalink - CPDLC • [G/G Datalink] • CMU
KC7 Delegation of Separation Assurance	This concept delegates some separation assurance tasks from the ground system to the cockpit (conflict detection, conflict resolution, monitoring of the resolution). The level of delegation can vary between total delegation, where the aircraft operates fully autonomously and limited delegation where the separation responsibility is partly delegated to the aircraft.	E7, E18	• Cockpit HMI capability • TIS-B Service • ASAS capability • ADS-B Service • Traffic Situation Awareness • Co-operative separation Application • Autonomous Aircraft • CD&R	• 4-D FMS • VDL mode 4 • Mode S • UAT • GNSS • A/A Datalink • A/G Datalink • CDTI • Database (Airspace)
KC8 Flexible use of Airspace	This concept allows particular parts of the airspace to be flexibly designated, in the time domain, for Civil Transport operations. This involves close co-operation between both Civil and Military authorities.	E1, E3, E4, E11, E14, E15, E18	• Cockpit HMI capability • DYNAV Service	• RNAV (FMS) • A/G Datalink • [G/G Datalink]
KC9 Collaborative Airspace Management	In this concept, the airspace across the whole ECAC region will be managed as a continuum in a flexible and dynamic way. The concept does not demand any new airborne functionality.	E1, E3, E4, E11, E14, E15, E18	• ATN	• [G/G Datalink]

3.3 Applicable Standards and Guidelines

3.3.1 Where possible, standards and recommended practices (SARPs), guidelines and system definitions should be applied to MA-AFAS and AFAS system designs. The following were specifically mentioned in the project reviews:

3.3.2 Documents Applicable to ADS

ICAO Documents:

- Data Link Applications Manual
- 1090MHz Extended Squitter SARPs
- Manual of Mode S Specific Services (doc 9688)
- VDL4 SARPs

RTCA/EUROCAE Documents:

- ADS-B 1090MHz MOPS
- ADS-B VDL4 MOPS
- ASSAP MOPS
- DO-242 – MASPS for ADS-B
- DO-243 – Guidance for Initial Implementation of CDTI
- DO-249 – Development & Implementation Planning Guide for ADS-B Applications

Eurocontrol Documents:

- ODIAC OCD
- AIRSAW Concept Document
- SCORS CONOPS

3.3.3 Documents Applicable to ATN

ICAO Documents:

- The ATN SARPS (2nd edition)
  - Sub-volume I: Introduction and System Level Requirements
  - Sub-volume II: Air-Ground Applications
  - Sub-volume V: Internet Communications Service (ICS)
- Annex 10

ARINC Documents:

- ARINC Characteristic 758, (Communications Management Unit Mark 2) (02/98)
  - Draft 5 of supplement 2 to ARINC Characteristics 758 CMU Mark 2 (25-10-99)
- ARINC Specification 637A in Draft
  - ARINC Specification 637A - Strawman V2.0 (8-10-99)
- ARINC Specification 761, (Second Generation Aviation Satellite Communication System, Aircraft Installation Provisions) (01/99)

3.3.4 Other relevant Documents

- ICAO document 9705 for CM DLIC CPDLC and ADS
- RTCA DO-212
- ICAO SARPs derived for CNS ATM-1
- ODIAC operational requirements

3.3.5 Standards currently under development should be monitored such that their application at a later date will be possible.

4 Glossary

4D	Four Dimensional
4D-TN	Four Dimensional Trajectory Negotiation
A/A	Air-to-Air
A/G	Air-to-Ground
ACARS	Aircraft Communications Addressing and Reporting System
ACAS	Airborne Collision Avoidance System
ACL	ATC Clearance
ACM	ATC Communications Management
ADC	Air Data Computer
ADLP	Airborne Datalink Processor
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance - Broadcast
ADS-C	Automatic Dependent Surveillance - Contract
AHMI	Airborne HMI
AIRSAW	Airborne Situational Awareness
AIS	Aeronautical Information Service
AMSS	Aeronautical Mobile Satellite System
AOC	Airline Operational Control
AOCC	Airline Operational Control Centre
AOCDLC	Airline Operation Centre DataLink Communication
API	Application Programming Interface
APR	Aircraft Position Reporting
ARINC	Aeronautical Radio Incorporated
ASAS	Airborne Separation Assurance System
ASM	Airspace Management
A-SMGCS	Advanced Surface Movement Guidance and Control System
ASOR	Allocation of Safety Objectives and Requirements
ASP	Actual Surveillance Performance
ASSAP	Airborne Surveillance and Separation Assurance Processing
ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
ATCo/ATCO	Air Traffic Controller
ATFM	Air Traffic Flow Management
ATIDS	Airport Target Identification System
ATIS	Air Traffic Information Service
ATM	Air Traffic Management
ATMAW	ATM Awareness
ATN	Aeronautical Telecommunications Network
ATS	Air Traffic Services
ATSAW	Air Traffic Situation Awareness
ATSU	Air Traffic Services Unit
ATTAS	Advanced Technologies Testing Aircraft System (DLR)
BIS	Boundary Intermediate System
CAP	Controller Access Parameters
CD&R	Conflict Detection & Resolution
CDM	Collaborative Decision Making
CDTI	Cockpit Display of Traffic Information
CDU	Control and Display Unit
CFL	Clearance Flight Level
CFMU	Central Flow Management Unit
CIC	Clearances & Information Communications
CM	Context Management

CMLF	Context Management Log-on Function
CMS	Common Modular Simulator
CMU	Communications Management Unit
CNS	Communication, Navigation and Surveillance
CONOPS	Concept of Operations
CORBA	Common Object Request Brokerage Architecture
CP	Conflict Probe
CPDLC	Controller Pilot DataLink Communication
CRD	Certification Requirements Document
CTOT	Calculated Take-Off Time
D/L	Datalink
DAP	Downlink of Aircraft Parameters
D-ATIS	Digital ATIS
DCDU	Datalink Control and Display Unit
DCL	Departure Clearance
D-FIS	Digital FIS
DGNSS	Differential GNSS
DIS	Distributed Interactive Simulation
DLIC	DataLink Initiation Capability
DOP	Daily Operational Plan
DSC	Downstream Clearances
DYNAV	Dynamic Route Availability
EATCHIP	European ATC Harmonisation and Integration Programme
EATMS	European ATM System
ECAC	European Civil Aviation Conference
EFIS	Electronic Flight Instrument System
EFMS	Experimental FMS
EOBT	Estimated Off-Block Time
ES	End System
EUROCAE	European Organisation for Civil Aviation Equipment
EVS	Enhanced Vision System
FAA	Federal Aviation Administration (USA)
FANS	Future Air Navigation System
FFAS	Free Flight AirSpace
FFEOP	Free Flight Operational Enhancements
FHA	Functional Hazard Analysis
FIS	Flight Information Service
FLIPCY	FLIght Plan ConsistenCY
FMS	Flight Management System
FPM	Flight Path Monitor
GBAS	Ground Based Augmentation System (for GNSS)
GCAS	Ground Collision Avoidance System
GES	Ground End System
GHMI	Ground HMI
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
HF	High Frequency
HIPS	Highly Interactive Problem Solver
HMI	Human Machine Interface
IAS	Indicated Airspeed
ICAO	International Civil Aviation Organisation
ICS	Internet Communications Service
IFR	Instrument Flight Rules

ILS	Instrument Landing System
ISAS	Integrated Situational Awareness System
MACAW	Malvern Cognitive Applied Walkthrough
MAS	Managed Airspace
MASPS	Minimum Aviation System Performance Standards
MCDU	Multi-purpose Control & Display Unit
MFD	Multi-function (cockpit) Display
MHz	Megahertz
MLS	Microwave Landing System
MMI	Man Machine Interface
MOPS	Minimum Operational Performance Standards
ND	Navigation Display
NEAN	North European ADS-B Network
NEAP	North European CNS/ATM Application Project
NMS	Network Management System
OCD	Operational Concept Document
ODIAC	Operational Development of Integrated Surveillance and Air Ground Data Communications
OED	Operational Environment Definition
OHA	Operational Hazard Analysis
OSA	Operational Safety Assessment
PATs	PHARE Advanced Tools
PD	PHARE Demonstration
PSR	Primary Surveillance Radar
PVD	Plan View Display
RA	Resolution Advisory
RNAV	Area Navigation
RNP	Required Navigation Performance
RSP	Required Surveillance Performance
RTA	Required Time of Arrival
RTCA	Radio Technical Commission for Aeronautics
SACTA	Spanish Air Traffic Control Automated System
SARPs	Standards and Recommended Practices
satcom	Satellite Communication System
SBAS	Space Based Augmentation System (for GNSS)
SC	Special Committee
SFL	Selected Flight Level
SICASP	SSR Improvements and Collision Avoidance System Panel
SPR	Safety and Performance Requirements
SSR	Secondary Surveillance Radar
STCA	Short Term Conflict Alert
SUA	Special Use Airspace
TA	Traffic Advisory
TCAS	Traffic Alert & Collision Avoidance System
TIS-B	Traffic Information Service – Broadcast
TMA	Terminal Movement Area
TP	Trajectory Predictor
TWDL	Two Way DataLink
UAT	Universal Asynchronous Transmitter
UMAS	Unmanaged Airspace
VDL	VHF Datalink
VDL-4	VHF DataLink mode 4
VFR	Visual Flight Rules
VHF	Very High Frequency

A Appendix A (Original Project Reviews)

These Reviews have been collated from the original submissions supplied by the WP1.1 MA-AFAS and AFAS Consortium partners with only minor formatting changes. To cut down on the document size, the partner-specific non-technical parts of the documents have been omitted (title pages, authorisation, contents etc.)

A.1 3FMS

A.1.1 Objectives

The objectives of the 3FMS (Free Flight, Flight Management System) project are:

- To prepare an early definition of a Flight Management System to operate a free flight ATM environment.
- To investigate the functional architecture of a free flight FMS for the Airbus family including the future A3XX.
- To explore the contributions an FMS can bring to the future European free flight ATM definition for optimising the airborne and ground functional distribution of the whole system
- To identify the FMS interoperability on a worldwide basis with respect to free flight ATM.

The main expected achievements of the project are:

- The identification of a free flight avionics architecture around the new FMS including EFIS and sensors
- The definition of the free flight functions for the new Airbus FMS
- An evaluation and demonstration of free flight operation with a prototype FMS in an airbus flight simulator in combination with a research ATC centre
- A list of recommendations for the implementation of the future free flight concepts in the European ATM environment.

Onboard functionality which will be addressed in the project:

- Aircraft separation using traffic information broadcast by surrounding traffic, detecting and resolving traffic conflicts
- Anticipatory terrain avoidance
- Weather avoidance based on on-board weather information
- Taxi management
- Communication functions (air-ground and air-air)
- Human machine interface functions

At the moment this review was performed the FMS prototype development was ongoing and the man-in-the-loop evaluation not yet conducted.

A.1.2 Methods used

Questions, which form the basis for the man-in-the-loop simulation experiment within the project, are:

- ☐ Conceptual:
  - Is 3FMS based free flight operation feasible and will it lead to a stable ATM system?
  - What are the requirements for future technology supporting the 3FMS to make the concept viable? Technologies like ADS-B, databases, data link etc.
  - Is the operation within new airspace structure acceptable for both pilots and controllers?

- ☐ Performance:
  - Are the conflicts detected and solved in time regarding safety and pilot/controller acceptance?
  - How sensitive is the 3FMS to traffic density in FFAS and is an increase of airspace capacity expected based on this sensitivity compared to current airspace capacity based pilot and controller feedback? Is this level of sensitivity sufficient for a 3FMS based free flight operation to be capable of handling an increase in airspace capacity compared to the current situation?
  - Does the use of 3FMS in FFAS reduce fuel consumption due to flight optimisation calculations in 4D compared to current operations leading to benefits for airlines?
  - Does the use of 3FMS in FFAS reduce trip time due to efficient conflict solving compared to current operations?
  - Does the use of 3FMS in FFAS reduce delays due to accurately meeting the RTA compared to current operation?
  - Can 3FMS support weather avoidance effective and efficiently other than current available weather information (weather radar for example)?

- ☐ Human factors: crew and ATCo
  - Do pilots accept the use of 3FMS in FFAS and MAS?
  - Does the crew workload increase while using the 3FMS in FFAS and MAS compared to current operation compared to the current operation under similar traffic conditions?
  - Are crew procedures in FFAS and MAS acceptable and valid?
  - Is the ATCo able to monitor and acquire sufficient situation awareness of the situation for intervening or providing support in the situation in case this is required during FFAS operation?
  - Do controllers accept the 3FMS MAS operation support by means of station keeping?

- ☐ Taxi:
  - Does the use of 3FMS reduce the time to taxi under normal circumstances compared to current operation?
  - Does the use of 3FMS improve the crew's situation awareness during the taxi phase?
  - Does the use of 3FMS reduce the crew workload during the taxi phase?

A.1.3 Main results

At the moment this review was performed the FMS prototype development was ongoing and the man-in-the-loop evaluation not yet conducted.

The design of the avionics however was frozen and consists of the following items:

- FMS
- Conflict detection algorithm (with respect to traffic, weather and terrain)
- Priority determination algorithm using air-air datalink
- Conflict resolution algorithm (in case priority has to be given to the intruder aircraft or in case of a conflict with weather or terrain)
- CDTI
- CPDLC (over simulated data link) for MAS operation and FFAS-MAS transition
- ADS-B and TIS-B (both simulated)
- Taxi management including taxi CPDLC

A pilot/controller in the loop evaluation is planned with a size of eight crews, with each crew participating for two days.

A.1.4 Key concepts and requirements identified

The key concept used in 3FMS is based on an ATM environment with three types of airspace:

- Free Flight Airspace (FFAS)
- Managed Airspace (MAS)
- Special Use Airspace (SUA)

In which FFAS forms the largest part of the airspace and MAS is concentrated around airports only.

<u>Operational procedure in FFAS</u>
Within FFAS traffic separation responsibility is fully delegated to the aircraft. However in FFAS also a limited number of non-free flight equipped aircraft are allowed which will be controlled by ATC.

<u>Operational procedure in MAS</u>
Within MAS traffic separation is the responsibility of ATC. However on a case to case basis the separation responsibility can be partly delegated to the aircraft. In those cases a properly equipped aircraft can follow another aircraft at a by ATC defined distance using the station keeping function.

A.2 AATMS

A.2.1 Objectives

The principal objective of AATMS was to develop an Advanced Flight Management System with a range of CNS/ATM functions and to demonstrate it in live flight trials in a realistic operational environment. Incorporation of ATN as communications environment, both in the design and in the trials, was a secondary objective. Development and demonstration of AOC functions in addition to ATM was a secondary objective. A further objective was the development of an ergonomic pilot interface, emphasising the avionics focus of the project.

The different modules of the AATMS demonstrator have been integrated in the flying test beds of DERA (BAC 1-11) and NLR (Cessna Citation) for validation. In both aircraft the necessary communication equipment is available. The demonstrator has been validated in real-life scenarios set up by pilots, airlines and ATS providers, i.e. the test beds have been sent out to typical flights in the envisaged ATC environment. By simulating the ATC and AOCC ground stations, the AATMS demonstrator could prove its operational and performance capabilities.

A.2.2 Methodology

In close collaboration with the AFMS project, AATMS followed a conventional system development methodology

The project started with the first phase of a typical project life cycle, the identification of user requirements. In this context the partners involved could build on extensive experience from related projects, in which the user requirements for future onboard CNS/ATM systems have been assessed from different points of view:

- the PHARE „Experimental FMS“ (EFMS)
- the German crew assistant prototype „Cockpit Assistant System“ (CASSY)
- the DG VII - APAS study „Functional requirements for Airport Ground Movement“
- the DG XII - APAS study „Advanced Flight Management System“
- the DG XIII - APAS study „Studies on Air Ground Communication Links“

This consolidation of user requirements was followed by the functional CNS/ATM specification in order to identify and assess possible onboard architectures and to define certification criteria. According to the selected architecture the different modules of the AATMS demonstrator were realised in hardware and software. Where possible, existing equipment or software was used or modified. Following the module development and testing at the different partners, the modules were integrated to the AATMS demonstrator and validated in flight trials. Messages from Air Traffic Control and the Airline Operation Control Centre were generated in ground simulators and transmitted via the ATN in order to validate the AATMS functions in real-life scenarios. Test runs with airline pilots were performed and evaluated. The project ended with the elaboration of a technology implementation plan in order to ensure the dissemination of the results and to bring European avionics industry in the position to start the product development.

A.2.3 Activities

A.2.3.1 Project Tasks

The elements addressed during the work included

1. Requirements Definition
2. Architectural Design
3. Detailed Design
4. Software Implementation
5. Software Integration
6. Hardware-Software Integration
7. Aircraft Integration
8. Demonstration Flights

A.2.3.2 Requirements Definition

The AATMS demonstrator was developed taking into account the results of EU programmes in the field of CNS/ATM and advanced airborne equipment, such as:

- PHARE (Programme for Harmonised ATM Research in Europe)
- FANSTIC II (Future ATM New Systems and Technologies Integration in Cockpits)
- GAAS (Generic Approach for ATM Systems)
- ADS Europe (Exploratory actions on ADS for European air traffic management systems)
- IMAGES 2000 (Integrated Modular Avionics, General Embedded System)

In each of the above referenced programmes/projects, one or more of the AATMS partners were represented. This ensured compliance of the AATMS project with work already done in Europe.

Both CAAs (AENA) and airlines (Lufthansa, Iberia, AerLingus) were strongly involved in the identification of the user needs. ATC controllers, planners and managers, airline managers and pilots actively reviewed and influenced the AATMS requirements. During a workshop in February 1996 in Madrid, the representatives from AENA and Iberia in particular provided useful comments and suggestions during the requirements definition.

A.2.3.3 Technical Specification

Based on the results of the user requirements assessment, communication, navigation, surveillance and ATM specifications were prepared. Aircraft categories and related candidate AATMS architectures were identified, measurement criteria were selected and defined and, finally, candidate architectures were analysed.

It was decided that the AATMS demonstrator should target mainly on regional aeroplanes not necessarily equipped with integrated avionics systems. As a conclusion, the consortium agreed on the selection of an architecture with the following main characteristics:

- The AATMS demonstrator consists of two separate units, an Advanced Flight Management System (AFMS) and a Communication Management Unit (CMU)
- The AFMS and the CMU are connected via Ethernet
- The AFMS serves as the airborne user process by hosting the ATC/AOC application software
- The AFMS also serves as the airborne user process for hosting the ADS application software
- The CMU serves as the airborne router

- The whole onboard equipment is ATN compatible

Based on this selection the architectural details of the AATMS for communication, navigation and airborne ATM functions and surveillance were specified in detail.

In the frame of this specification work, it was decided to develop two AFMS demonstrators within this project

- A short-term demonstrator (2005 timeframe)
- A medium-term demonstrator (2010 timeframe)

This decision resulted in the most significant change of the planned work.

The technical parameters of the AFMS are summarised in the following.

- Communication (aircraft/ATC and aircraft/AOCC):
  VHF Voice and VHF/SATCOM Data Link with experimental ATN routing and end system
  Optimised pilot interface with data link via prototype CMU
- Navigation:
  4D navigation and guidance based on GNSS (down to non-precision minima)
  Compliance with the "Required Navigation Performance" (RNP) concept
  Pertinent database management
- Surveillance:
  Automatic Dependent Surveillance (ADS)
- ATM functions:
  Weather/airport information uplink
  AOCC up-/downlink
  4D flight planning and flight plan negotiation with ATC and AOCC
  Optimised pilot interface for onboard flight planning and negotiation

A.2.3.4 Specific Comments

- In the definition of operational requirements, use was made of airline and ATS operator inputs, provided by Iberia, Lufthansa and AENA.
- Air-Ground data links based on VDL Mode 2 and on AMSS SatCom were used during the demonstration flights.
- The air-ground ATN communications environment was co-ordinated by NLR, making use of facilities developed by PHARE and ARINC.
- Two functionally different AFMS demonstration units were constructed, one representing the 2005 scenario (NFS, using the NFS-5000), the other the 2010 scenario (Marconi)

A.2.4 Results of AATMS

A.2.4.1 Products

The principal products of the AATMS project were

- Short-term AFMS technology demonstrator
- Medium-term AFMS technology demonstrator
- Software Applications for Airline Operations Centre
- ATC ground system simulator
- ATN compliant data link communications infrastructure

A.2.4.2 The AATMS Architecture

Relying on the conclusions of the architecture assessment putting forward compliance with ATN orientation and laying emphasis on the use of existing means (either on the test aircraft or on ground), figure 1 below shows the different elements involved in the communication chain, as resulting from the AATMS demonstrator. The equipment involved in the air-ground data link communication are those necessary for the access of the two addressed sub-networks, namely VHF and SatCom equipment, and the airborne communication router.

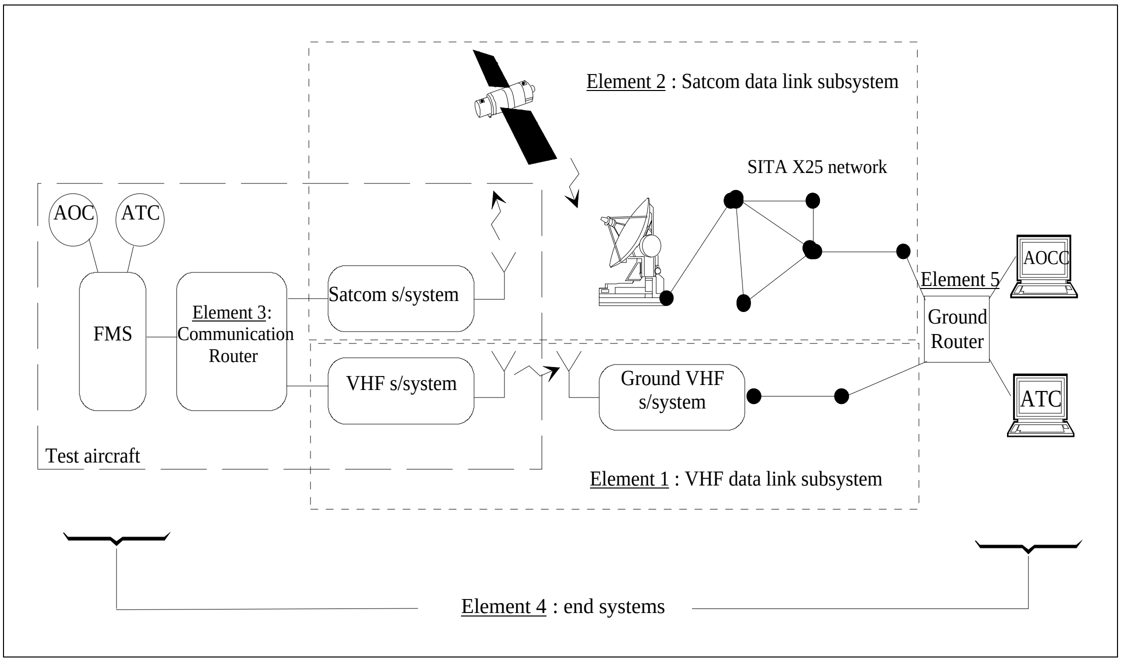


Figure 1: The AATMS Architecture

The overall AATMS architecture can be divided into four main elements:

- Advanced Flight Management System as Airborne End System
- Airborne ATN Router and End System
- SatCom and VHF Data Link Subsystems
- ATC and AOCC Ground Stations as Ground End System

A.2.4.3 Short-term Demonstrator AFMS Functions

The NFS-5000 realises functions of an advanced Flight Management System. Through its advanced, object-orientated graphical user interface it allows the pilot to easily enter and modify flight plans. Aircraft position data can be received from a flight simulator (or an external GPS receiver and various aircraft systems). Via an Ethernet interface to ATC and AOC ground stations (or an airborne router) the NFS-5000 is able to meet the requirements of the future CNS/ATM environment. The following main functions have been realised:

- Planning / Guidance
  4D-flight plan editing and flight planning
  Autorouting function that automates the flight plan editing process
  Vectoring function that integrates ATC radar vectoring commands into the flight plan
  Integration of pre-stored flight plans
  Integration of uplinked flight plans and constraints from Airline Operation Centre (AOC) or ATC
  4D trajectory prediction taking into account performance parameters and meteo information
  4D guidance capabilities (RTA)

- Crew Interface
  Object-oriented graphical display design
  Enlarged display size on the CDU
  Direct manipulation technique by use of a control-cursor device
  Minimisation of alphanumeric inputs due to pre-definitions
  Use of line select keys and a rotator knob

- CNS/ATM
  ATN-compatible CPDLC with air traffic control
  AOCDLC with the airline via ATN
  ATN-compatible generation and handling of ADS-C reports

The NFS-5000 has been designed as an FMS for aircraft, which are not equipped with, integrated systems. The functionality and performance of the NFS-5000, therefore, have been designed to serve the short to medium range FMS aircraft retrofit market (turboprops, business jets and light air transport jets). For this reason, the short-term planning and guidance functions concentrate on today's situation with additional capabilities for automated flight plan editing (auto routeing), integration of radar vectors in the flight plan (vectoring) as well as integration of uplinked flight plans and flight plan constraints but without trajectory negotiation capabilities. With regard to the crew interface NFS-5000 follows a concept to realise an integrated control, display and flight management unit with a graphical display on this CDU, intended on aircraft which are not equipped with integrated avionics systems. Therefore, the NFS-5000 does not make use of the EFIS or any speech input/output systems.

A.2.4.4 Medium-Term Demonstrator AFMS Functions

The medium-term AFMS further provides 4D guidance to the active flight plan. The guidance has 2 modes of operation, *Continuous Mode* which is where the guidance continually tries to keep the aircraft exactly on the flight plan and *Event Driven Mode* which is where the guidance only makes corrections when the aircraft is going outside a pre-defined tolerance from the flight plan. By allowing the guidance to operate in 2 modes, the system is able to take advantage of the differing accuracy with which the aircraft needs to be flown depending on the phase of flight. Therefore, for phases of flight such as approach, the aircraft will be guided in continuous mode, maintaining maximum adherence to the flight plan and so maximising safety. In phases of flight such as late climb, cruise, and early descent, the aircraft will be guided in event driven mode, allowing the aircraft to be flown more efficiently.

The medium-term AFMS also supports data link communications with the ATC. It will allow strategic negotiation of flight plan between the crew and the ATC during the flight. This will give the crew better situation awareness as they will have longer term route clearances than currently experienced and the ATC will benefit from the greater detail contained within the flight plan provided to them by the aircraft. The medium-term AFMS will also provide a Surveillance function by the use of Automatic Dependent Surveillance (ADS) data link as envisaged by the ICAO with the CNS/ATM concept. This will allow the ATC to monitor the aircraft's progress and have an indication of its intent by knowing its next waypoint together with estimated time of arrival and distance to it.

A.2.4.5 ATC Simulator

Summary
An important element of the AATMS set-up was the ATC simulator, provided by NLR's NARSIM environment. For the demonstration of ATC data-link communication in support of the AATMS fixed wing flight trials, NARSIM was upgraded. The main enhancements were focused on interfacing with the PHARE Aeronautical Telecommunications Network (PATN) and the provision of graphical Human Machine Interfaces for the ATCo, to enable CPDLC and ADS data link dialogues. For this reason the 'Plan View Display' (PVD) of the Controller Working Position was extended with ADS and CPDLC functionality. ADS messages were integrated in the radar display, they show up as a 'blip' on the PVD to support the surveillance function for the controller. The CPDLC interface module showed an intuitive graphical user interface for the air traffic controller coupled with the CPDLC data-link application. This interface enabled the operator to compose and send messages to be uplinked and to process and reply down linked requests. The CPDLC interface was displayed on the right-hand bottom corner on top of the PVD.

Air Traffic Controller Involvement
Two highly experienced air traffic controllers of AENA, Spain were involved as human operators at the NARSIM site during the AATMS demonstration trials. One of the controllers had a background of approach controller, the other as both en-route and approach controller. Their main task was to control the Citation aircraft during the demonstrations by means of CPDLC messages according to a pre-determined script.

A training period of three days was introduced to acquaintance the controllers with the procedure, airspace and system interfaces specific for the AATMS trials.

During the actual flight trials one controller per trial session participated in the ATC part of the scripted scenarios. Data recording was performed on all datalink related messages within the system, for later use in the post-processing and analysis phase.

Air Traffic Controller Evaluation
During the actual flight trial demonstrations sometimes round trip delay times of over 30 seconds were experienced (mainly when only the SatCom subnetwork was active). The controllers indicated that an acceptable round trip delay between uplink and reply was 5 to 10 seconds. For approach control even faster response times are desirable.

Taking pilot response times into account, these figures are quite a challenge to achieve with the current state of technology and operations.

A.2.4.6 AOC Ground Simulator

The software applications for Airline Operations Centres (AOC) consisted of an AOC Ground Simulator and flight plan generators.

The AOC Ground Simulator is designed to simulate the everyday operational control that an airline has with its aircraft. The AOC Ground Simulator has the ability to send and receive messages to and from the aircraft regardless of the aircraft's flight status. Message types that can be sent/received include weather information, flight plans, position reports, fuel status etc. All of the messages that may be demonstrated greatly improve the safety of an aircraft and provide the airline with greater efficiency.

The integration of a datalink into an Airline Operations Centre allows for greater forward planning and congestion avoidance. If all the airlines that operate within a given airspace provide their flight plans and their position information into a centre database, airline operations dispatcher can alleviate congestion before it becomes serious by slowing down, speeding up or diverting aircraft before the aircraft reach the given airspace.

The flight plan generator is designed to ease the preparation and verification of flight plans for use with the AOC Simulator software application. New or previously designed flight plans can be edited and updated, with new meteorological data for instance, via a user friendly GUI.

With the increase in air traffic over major world centres, flight planning is becoming more difficult. The introduction of a centralised publishing system, where all flight plans from all airlines are available in all stages of development will allow an individual airline to avoid congested airspace occurring, in the normal course of events.

One of the main emphasis in this context lies on the realisation of AOC services with a high potential for subsequent industrial applications decision aid systems and error reporting environment dedicated to Airline companies.

A.2.4.7 ATN Infrastructure

Description
The communication infrastructure as has been used within the AATMS project, was based upon the 'PATN', the PHARE implementation of the Aeronautical Telecommunications Network (ATN). Within the AATMS project the PHARE implementation has been modified to the requirements of the AATMS project. These modifications involve the addition of the VHF Data link (VDL) mobile subnetwork to the existing SatCom subnetwork, and the modification of the Application Service Elements (ASEs).

For the demonstrator, two configurations were used:

1. Laboratory test configuration used for the integration of the CDNU (the hardware implementation of the short-term AFMS demonstrator), PATN, NARSIM and AOC ground station both stationed at the NLR facilities in Amsterdam. It provides the same ATN functionality as is used in the real flight trials, only makes use of the NLR office LAN to connect the air and ground BIS/ES.
2. Aircraft operational configuration, which is used for the interconnection of one of the NLR experimental aircraft - the Cessna Citation II - with the NARSIM ATC simulator of NLR Amsterdam and the AOC ground station, using the satellite and the VDL Mode 2 mobile subnetworks.

Figure 2 shows a diagram of the ATN architecture.

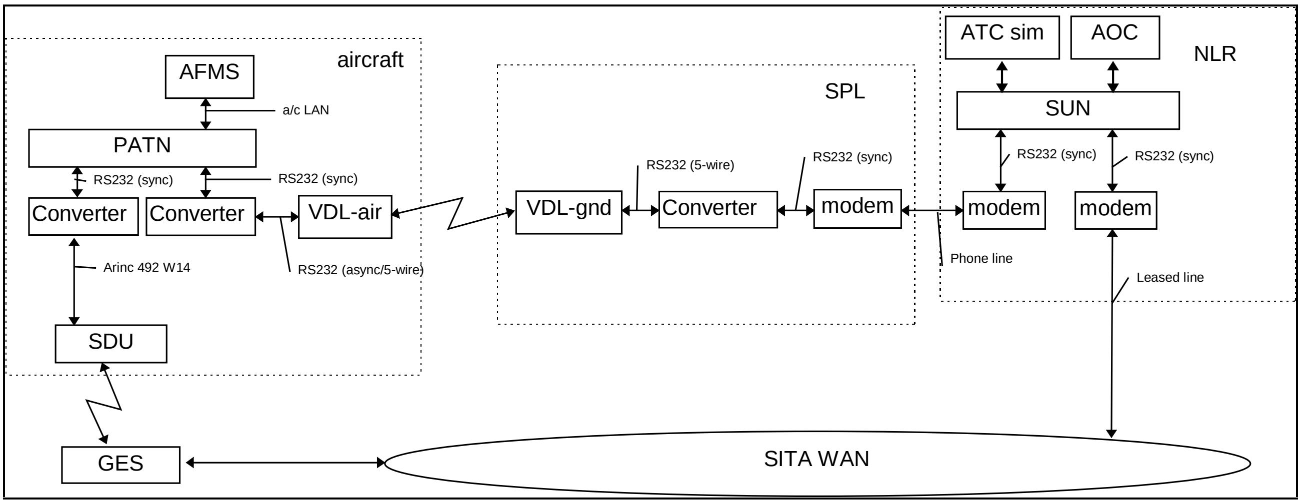


Figure 2: ATN architecture

For AATMS, two mobile air-ground subnetworks were used: VHF Digital Link (VDL) Mode 2 and AMSS satellite (SatCom) subnetworks. VDL Mode 2 provides a low-cost, high-speed connection, using terrestrial transceivers and is therefore limited in its geographical coverage. SatCom provides a more expensive, low-performance subnetwork providing nearly global coverage. For a data communications infrastructure, the combination of the complementary characteristics of these subnetworks is very interesting.

A.2.4.8 Observations Regarding ATN

1. The transfer delay of an X.25 message was about 1 second for VDL Mode2. This delay was independent of the distance between aircraft and ground station.
2. A CPDLC message experienced an average transfer delay of about 5 sec. It is found that this is mainly due to encoding/decoding by upper and lower stack, since the X.25 delay is always approx. 1 second.
3. The average VDL coverage is found to be approximately 135 km at FL100.
4. Signalling the user of the loss of the subnetwork (about 2 minutes) takes too long.
5. Although SatCom did perform well during shakedown, it was found that network congestion errors happened frequently during the demonstration phase. These network congestion errors are caused by the SatCom subnetwork itself, and not by the ATN BIS/ES. It was also found that the performance is very unpredictable, and dependent on time of day.
6. The average X.25 transfer delay was about 15 sec for SatCom.
7. The average CPDLC/ADS message transfer delay was about 20 sec, while transfer delays up to 36 seconds were experienced. When SatCom was the only available subnetwork, the ADS period was set to at least 30 seconds. This was required to avoid network congestion. The SatCom throughput was found to be far too small to allow the high data-volume AOC messages, e.g. flight plans or meteo to be exchanged.

A.2.5 Achievements and Findings

In summary, the main achievements and findings of the project were:

1. Construction of two demonstration AFMS's conforming with SARPs.
2. Construction of demonstration ground infrastructure for ATM and AOC.
3. Successful demonstration of the AFMS in flight trials in two aircraft
    - DERA BAC111
    - NLR Cessna Citation
4. Demonstration that, given suitable CNS infrastructure, ATM functions can be operated successfully, both technically (reliability, performance) and in terms of human factors (both Pilot and Controller). However, in both technical and human-factors areas, shortcomings were identified.
5. A multi-subnetwork ATN network was successfully demonstrated with an aircraft in flight.
6. Performance of the SatCom subnet was problematical in being generally slow and also intermittent on occasion.
7. Performance of the VDL subnet was very good, however the load conditions were unrepresentative
8. Pilot interaction with the CDU was occasionally unsatisfactory in generating additional (sometimes excessive) pilot workload

A.3 AFMS

A.3.1 Objectives

The 4th Framework project Advanced Flight Management System (AFMS) has been tasked by the Directorate General DGXII of the European Commission under Contract-No. BRPR-CT95-0044. The project was co-ordinated by DaimlerChrysler Aerospace NFS (DASA-NFS). Further team members were BAE Systems, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Skysoft Portugal, Eurocopter Deutschland (ECD), Rheinisch-Westfälische Technische Hochschule Aachen (RWTH), Defence Evaluation and Research Agency (DERA), Nationaal Lucht- en Ruimtevaartlaboratorium (NLR), Bertin et Cie (BTN) and Alenia Difesa (AD). The duration of the project was from 01/12/95 until 31/12/98.

The Flight Management System (FMS) of today has introduced operational advantages and significant cost savings through offering the possibility of an automatic, fuel-efficient flight from take-off to landing. However, the FMS with its high level of automation has changed the pilot’s role considerably. This has caused dominant problems with respect to human factors. Furthermore, the present FMS technique is not able to meet the requirements of the future CNS/ATM (Communication, Navigation, Surveillance, Air Traffic Management) scenario.

For that reason, this project concentrated on the development and evaluation of a demonstrator for an Advanced Flight Management System (AFMS). The objectives of the AFMS programme were the development and demonstration of a set of advanced Flight Management Systems (FMS) being able to meet the requirements of the future Air Traffic Management (ATM) environment. The main emphasis was on ensuring that flight management functions were compatible with the future European CNS/ATM environment, both in the short term (around the time frame of 2005) and the medium term (from 2005 to 2020). This required the FMSs to handle flight planning and negotiation via a data link, which in turn led to the need to greatly enhance the Human Machine Interface (HMI) to ensure good crew situation awareness of these additional functions. To address the HMI, FMSs were produced that could textually and graphically display and edit the flight plan.

Since the project partners are deeply involved in research work in this field the approach was to base development on pertinent systems such as the "Experimental FMS" (EFMS) from the PHARE programme or the German "Cockpit Assistant System" (CASSY). The development was further based on the outcome of the study project "AFMS" (APAS-Task 2.1) in which the functional requirements for an AFMS were consolidated. Therefore, the final project objective was to develop an AFMS demonstrator, based on the EFMS prototype, the CASSY prototype and the results of the AFMS study, and to validate this demonstrator in a simulated ATM environment.

The project objective was attained by a 37-month project that covered the following phases:

- definition of functional requirements using the results and specifications from previous FMS related programmes performed by the partnership (PHARE-EFMS, APAS-AFMS, CASSY)
- development of software code for the different modules of a demonstrator
- integration of the modules into the flight simulators and validation of the demonstrator in a simulated ATM environment
- exploitation of the results with regard to new products for European avionics industry

A.3.2 Methods Used

During the consolidation of the user requirements, it became apparent that there were a number of differing requirements emerging for the short term, i.e. the next 5 to 10 years, the medium term of 10 to 15 years and for differences between fixed wing and rotary wing aircraft. Consequently it was decided to develop and validate two fixed wing AFMS demonstrator versions, targeted at the short term and the medium term future operating environment. A further version of the AFMS demonstrator would concentrate on helicopter aspects. This development was based on a common system design and harmonised by putting certain emphasis on different aspects of the AFMS. This approach was adopted as it was not expected that a single demonstrator would be able to meet all the different aspects of the operational ATM environment, whilst commonality and upgrade paths between the demonstrators was maintained as much as possible.

The fixed wing systems were both adapted in the ATTAS simulator at DLR in Braunschweig and tested by professional pilots in accordance with created scenario flights. The simulation trials for the rotary wing demonstrator, took place in Eurocopter's fixed base helicopter simulator. Flight trials were not in the scope of the project. For the realisation of the data link message transfer in both cases the FMSs were linked to ATC and AOC ground simulators that were also designed and developed in the frame of the project.

A.3.3 Main Results

A.3.3.1 Short term fixed wing AFMS

The *short term fixed wing* AFMS comprises of a DZUS-sized integrated control, display and navigation unit with a built-in active matrix colour display and the respective software modules integrated in this unit. This hardware box - also named NFS-5000 - has been developed under the Telematics Application Programme (TAP) projects, AATMS and FARAWAY. The NFS-5000 realises functions of an advanced flight management system. Through its advanced, object-orientated graphical user interface it allows the pilot to easily enter and modify flight plans. Aircraft position data can be received from a flight simulator (or an external GPS receiver and various aircraft systems).

The NFS-5000 has been designed as a FMS for aircraft that are not equipped with integrated systems. The functionality and performance of the NFS-5000, therefore, have been designed to serve the short to medium range FMS aircraft retrofit market (turboprops, business jets and light air transport jets). For this reason, the short-term planning and guidance functions concentrate on today's situation with additional capabilities for automated flight plan editing (autorouting), integration of radar vectors in the flight plan (vectoring), as well as integration of uplinked flight plans and flight plan constraints but without trajectory negotiation capabilities. With regard to the crew interface, the NFS-5000 follows a concept to realise an integrated control, display and flight management unit with a graphical display on this CDU, intended for aircraft which are not equipped with integrated avionics systems.

For the evaluation the short-term demonstrator was adapted in the ATTAS simulator at DLR in Braunschweig and was tested by 10 pilots in accordance with the created scenario flight from Boscombe Down to Amsterdam Schiphol. The main conclusions from the evaluation were that the system works without any major difficulties, although the overall performance for response times was too slow. Overall the pilots envisaged that they could use such a system in the future. The most innovative aspect certainly lies in the fact that the NFS-5000 integrates advanced flight management functions including ATN compatible datalink applications in one box. This enables a cost-effective use of an ATN end system especially in the retrofit and general aviation sector. It opens a realistic opportunity since with this concept all participants in the ATM environment can be reached and fitted with the respective equipment leading to growing market opportunities for the respective avionics suppliers.

A.3.3.2 Medium term fixed wing AFMS

The *medium term fixed wing* AFMS demonstrator represents a software prototype system supporting 4D flight planning, i.e. generating a 4D-trajectory with respect to aircraft position, altitude and time, and negotiation of a 4D-trajectory with ATC/ATM facilities by means of a data link connection. The underlying operational mode refers to strategic planning, but depending on the time horizon applied may include tactical control advisories as well. However, immediate action requests from ATC/ATM or AOCC for emergency situations are out of the scope. The demonstrator software is based on the PHARE EFMS development, with FMS functionality enhanced by additional and/or extended flight planning, flight monitoring and 4D-trajectory negotiation modules and sub-modules. The crew interface concept represents a means for the pilot to operate the demonstrator system by direct access via touch-pad input on Navigation Display and Advanced CDU, i.e. the role of the crew as manager of the airborne part of a future ATM system and overall system integrity are supported. The crew interface software utilises the basic ideas of the PHARE EFMS, but is further developed regarding integrity of the particular flight management tasks, aircraft supervision and 4D-trajectory negotiation. The demonstrator supports combined operation of different display devices presenting identical information in an alphanumeric or graphic format, on CDU and ND, respectively.

This demonstrator was integrated into the ATTAS Experimental Cockpit simulation environment and tested by 14 pilots by means of two to three scenario flights from Boscombe Down to Amsterdam Schiphol.

A.3.3.3 Medium term rotary wing AFMS

The *medium term rotary wing* AFMS provides full auto 4D (i.e. longitude, latitude, altitude and time) flight planning. It uses an accurate aircraft model in combination with the latest available weather data (comprising of wind speed and direction, temperature and QNH) to accurately predict the helicopter's flight plan. Due to the accuracy of the prediction, the crew are able to give more reliable and accurate arrival time estimates. The use of a special approach generator allows the helicopter to land at unprepared airfields. Also, using the fuel model contained within the 4D flight planner, the crew are able to compare the fuel efficiency and arrival times of one route against another to determine the most cost effective option for a selected cost index. The medium term rotary wing AFMS further provides 4D guidance to the active flight plan. The guidance has 2 modes of operation, continuous mode, which is where the guidance continually tries to keep the aircraft exactly on the flight plan, and event driven mode, which is where the guidance only makes corrections when the aircraft is going outside a pre-defined tolerance from the flight plan. By allowing the guidance to operate in 2 modes, the system is able to take advantage of the differing accuracy with which the aircraft needs to be flown depending on the phase of flight. Therefore, for phases of flight such as approach, the aircraft will be guided in continuous mode, maintaining maximum adherence to the flight plan and so maximising safety. In phases of flight such as late climb, cruise, and early descent, the aircraft will be guided in event driven mode, allowing the aircraft to be flown more efficiently and with greater passenger comfort as the changes in autopilot will be minimised.

The *medium term rotary wing* AFMS demonstrator also supports datalink communications with the ATC, allowing strategic negotiation of flight plans between the crew and the ATC during the flight. It also provides Automatic Dependent Surveillance (ADS) via data link, allowing the ATC to monitor the aircraft's progress and have an indication of its intent by knowing its next waypoint together with estimated time of arrival and distance to it. The medium term rotary wing AFMS also comprises a more integrated Human Machine Interface (HMI) than standard FMS. It comprises a Navigation Display that has a cursor control device, as well as a more conventional Control and Display Unit (CDU) although with a task oriented page structure. The Navigation Display is a map display upon which the flight plan and flight path information is overlaid. The cursor control device allows the crew to graphically edit the flight plan in conjunction with function and line select keys. The Navigation Display supports track up and north up displays for monitoring and editing the flight plan, and it also supports profile displays to allow crew to assimilate the vertical aspect of the flight path. Time information is given textually at pertinent points along the flight plan. By linking the Navigation Display and the CDU together, a selection or edit on one device will be reflected almost instantaneously on the other.

The simulation trials for this demonstrator took place in Eurocopter's fixed base helicopter simulator. As a result of the test and evaluation runs it can be stated that the overall system concept of the medium term AFMS proved to be robust without major operational problems. Due to the advanced crew interface concept it could be shown that pilot acceptance is improved, even though operated in the much more complex and challenging ATC environment of the year 2015. Moreover, the evaluation runs proved that training times may be reduced considerably, as the crew interface is much more compliant to the pilot's view of the environment. Consequently, the medium term AFMS met the operational goals as a demonstrator suitable as basis for product development.

A.3.3.4 ATC and AOC ground simulators

As part of the project, two ground simulators have been developed to validate the implementation of the PHARE ATN compliant datalink services for both ATM (CPDLC, 4DTN, ADS applications) and AOC (AOC application). These simulators allow rapid prototyping and operational validation of the proposed datalinking activities including the uplinking and downlinking of AOC and ATM messages and protocols. Furthermore, the ATN-like communication protocol libraries permit easy testing of peer-to-peer communication either at application or transport compliant levels. One of the main results in this context lies in the realisation of AOC services with a high potential for subsequent industrial application decision aid systems and error reporting environments dedicated to airline companies.

A.3.4 Key Concepts and Requirements Identified

The results of AFMS will build one important basis for the development work in MA-AFAS. This does not only cover the avionics package development itself but also ground station and communication related aspects. Since most of the AFMS partners are now actively involved in MA-AFAS a continuous information transfer and a suitable handling of IPR issues can be assured.

With regard to the future CNS/ATM technology the following key concepts have been validated:

- Automatic Dependent Surveillance (ADS) function following design guidelines as defined in ARINC745-2
- Airborne communication functions allowing the transfer of various messages (ADS, CPDLC and 4D Trajectory Negotiation) via an ATN router from the aircraft to and from ATC
- Airborne communication functions allowing the transfer of various messages via an ATN router from the aircraft to and from AOC
- Airborne HMI that allows the handling of communication messages in correlation with flight planning interactions (i.e. presentation of communication messages on the CDU and the EFIS)

The following key requirements for the onboard avionics have been worked out and realised in AFMS:

- the onboard avionics shall support ATN compliant data link communication
- the onboard avionics shall be able to receive, present and process messages from the ground stations (CPDLC and AOCDLC)
- the onboard avionics shall enable the crew to generate messages to be down linked to ATC and AOC (CPDLC and AOCDLC)
- the onboard avionics shall enable four-dimensional trajectory negotiation with ATC
- the onboard avionics shall incorporate an ADS function
- the onboard avionics shall have 4D navigation capabilities
- the onboard avionics shall be capable of generating optimum four-dimensional trajectories
- the onboard avionics shall be capable of four-dimensional guiding
- the onboard HMI shall enable intuitive interaction for flight planning tasks on the EFIS and the CDU (supported by suitable input devices such as cursor control device)
- the onboard HMI shall incorporate the presentation and generation of communication messages on the EFIS and the CDU
- the onboard HMI shall incorporate information received via data link into the overall situation representation (for example graphical presentation of the updated trajectory)

The available specification documents as well as the validation results are expected to significantly influence the avionics package design of MA-AFAS.

Since related ground functions for ATC and AOC are available as well from AFMS it is expected that especially the AOC ground station development will base on the work already done.

A.4 ARAMIS

A.4.1 Objectives

The principal objective of ARAMIS was to demonstrate how accurate predictions of aircraft movements could be exploited in a software-based Controller tool to provide, graphically, Forecast trajectories, and Controller advisories which would permit reduced separations on approach and landing. The main technical objective was to achieve a forecast accuracy of 1 sec. on touchdown.

The methodological approach chosen for ARAMIS was essentially to construct a software demonstrator in the form of a prototype Controller aid. The Controller aid was then trialed by volunteer Controllers at EEC, using a simulation environment provided by ESCAPE.

A.4.2 Methods Used

The elements addressed during the work included

1. Airline survey of standard approach policies
2. High-accuracy Performance Modelling of approach and landing
3. Graphical MMI for Controller display and Controller inputs
4. Air-Ground data link

A.4.2.1 Airline Survey

In order to achieve the required modelling accuracy, it was necessary to ascertain how individual airlines flew aircraft on approach at specific airports (Heathrow, Milan Linate and Paris CDG). A survey by means of questionnaire of selected airlines for selected aircraft (Alitalia, BA, Air France, B737, A320) was carried out. This provided data on flight mechanics aspects such as flap settings, use of air brakes etc. this represented a vital input to the performance models.

A.4.2.2 Performance Models

NLR's aircraft performance models (forming part of NARSIM) were used as the basis of an enhanced model, capable of providing the required accuracy by modelling of secondary effects.

A.4.2.3 Graphical MMI

Clear, intuitive presentation of status and advisories to the Controller was provided by an X Windows-based graphical user interface. A set of standard approach paths was used in the models, which supported a small number of free parameters (such as base leg extension). These parameterised models formed the basis of the performance models and the advisory generation as well as the graphical display.

A.4.2.4 Air-Ground Data Link

Use of air-ground data link was incorporated in the tool, to permit essential airborne status data to be downlinked. The mechanism chosen for control was the standard voice-based Controller to Pilot delivery of clearances.

A.4.3 Main Results

The main achievements of the project were:

1. Construction of a software Controller aid with the required functions listed above.
2. Evaluation of the tool in a realistic simulated environment with human Controllers.
3. Identification of the vital features necessary to achieve high-accuracy trajectory forecasts. These included
   - Detailed data on aircraft flight control and engine settings
   - Very extensive performance data as parameters for the performance models (in numerical tabular form)
   - Intuitive Controller interface
4. Demonstration that, under suitable conditions and given the availability of necessary data, aircraft arrival times could be controlled much more accurately than conventionally. Although the 1-sec. objective is probably not achievable routinely, valuable improvements can be made, enabling separations to be reduced from present values with no impact on safety.

A.5 ATM Strategy for 2000+

A.5.1 Introduction

The Air Traffic Management (ATM) Strategy for the years 2000+ has been developed at the request of the Transport Ministers of the European Civil Aviation Conference (ECAC) against the background of an actual and forecast increase in European Air Traffic, which will demand a quantum increase in ATM and airspace capacity. The Strategy describes the processes and measures by which the forecast demand may be satisfied, while improving aviation safety.

The ATM Strategy for 2000+ follows on from the ECAC Strategies for the 90' s. It incorporates the on-going final phase of the European Air Traffic Control Harmonisation and Integration Programme (EATCHIP) and the scope of the former Airport/Air Traffic Services Interface Programme (APATSI).

The Strategy Document comprises two volumes:

Volume 1 - this document - provides the basis for, and the background to, the Strategy. It describes the Overall Objective, the high-level principles and major objectives which govern the Strategy, an outline of the main lines of action to effect change, and the general management principles to be adopted.

Volume 2 contains the detailed rationale for change, and guidance on the activities, which are needed to meet the Strategy objectives.

The Strategy document is supported by a related set of technical documents, including the Operational Concept Document. The application of the Strategy is inter-related to the operational and functional options described in the Operational Concept Document. Both documents will need to be reviewed and revised in parallel to ensure that they remain congruent.

A.5.2 Methods used

At the fifth meeting of ECAC Transport Ministers (MATSE/5) in Copenhagen on 14th February 1997, Ministers adopted an Institutional Strategy for Air Traffic Management (ATM) in Europe and decided that the EUROCONTROL revised Convention, which was signed later in 1997, would be the legal instrument for the implementation of the ECAC ATM Institutional Strategy. In addition, the Ministers requested, for consideration at their next meeting, a proposal for a comprehensive, ' gate-to-gate' orientated ATM Strategy for the years 2000+ as a follow-up to the En-Route and Airport Strategies for the 1990s.

After consulting with the Directors General of Civil Aviation of the ECAC States, the Director General of EUROCONTROL established an ATM 2000+ Strategy Board in October 1997 to develop, and deliver by November 1998, a strategy proposal describing how the ATM network in Europe should develop in the early part of the 21st Century. The Board comprised senior managers from the States, the Air Traffic Control Service Providers, the Airport Operators, the Airspace Users, ECAC, ICAO, the European Commission, JAA, NATO, FAA, AECMA, Aircraft and ATC Equipment Manufacturers, EUROCAE, the Professional Associations and the EUROCONTROL Agency.

The Board reviewed past and present ATM studies and activities conducted both in Europe and other regions. Supported by EUROCONTROL Agency staff, and drawing on the expertise and work of the Board Members and the organisations they represented, proposed texts were then compiled and put through a comprehensive consultation process with the aviation community. The final Strategy Proposal developed by the Board falls within the framework of the ECAC Institutional Strategy and of the regional and global CNS/ATM plans being developed by ICAO.

The Strategy proposal was presented to the Director General of EUROCONTROL in late October 1998.

A.5.3 Main results

The Major Strategic Objectives

1. Safety

To improve safety levels by ensuring that the number of ATM induced accidents and serious or risk bearing incidents do not increase and, where possible, decrease.

Safety is of the highest priority in aviation. The main purpose of ATM services is to ensure the safe separation of aircraft, both in the air and on the ground, while maintaining the most efficient operational and economic conditions.

2. Economics

To reduce the direct and indirect ATM-related costs per unit of aircraft operations.

Economic considerations should be an integral part of the development, implementation, operational and cost-recovery stages to ensure prioritisation of the allocation and usage of capital and resources at each decision stage. Cost reduction and value-for-money must be essential elements for ATM. All direct costs of the service providers and indirect costs, which include the costs of delays due to ATM, flight inefficiency and on-board equipment, need to be considered. In the future, other indirect costs, such as environmental costs, may also be included.

3. Capacity

To provide sufficient capacity to accommodate the demand in typical busy hour periods without imposing significant operational, economic or environmental penalties under normal circumstances.

To enable airports to make the best use of possible capacity, as determined by the infrastructure in place (land-side and air-side),political and environmental restrictions, and the economic handling of the traffic demand.

Capacity is a complex mix of access to airports, airspace and services, predictability of schedules, flexibility of operations, flight efficiency, delay, and network effects. ATM and airspace capacity-related aspects also include controller workload, weather conditions, availability of communications, navigation and surveillance systems, and other factors. The most visible symptom of capacity shortfall is the level of delays.

4. Environment

To work with ICAO and its member States to obtain improvements in ATM, in particular the accelerated implementation of CNS/ATM concepts, procedures and systems which help to mitigate the impact of aviation on the environment.

The environmental effects of aviation are an increasingly important political, economic and social issue. One of the goals of the Strategy is to accommodate environmental considerations in an integrated and expanded European ATM network. Others are to identify and tackle environmental problems posed by traffic growth, and to progressively improve environmental performance on a network-wide basis.

5. National Security and Defence Requirements

To determine new mechanisms, criteria and structures to enhance civil-military co-operation and co-ordination.

To ensure access to airspace for military purposes through the implementation of special procedures where necessary.

ATM has to support national security in respect of the identification of flights entering a State' s national territory, and Air Defence organisations have to be provided with all ATM information relevant to their task. ATM also has to support day-to-day military operations through the provision of, and access to, sufficient airspace for military needs. The exchange of information between civil and military ATM service providers is essential for civil-military co-ordination, and can only be achieved if civil and military systems are compatible or inter-operable.

6. Uniformity
To ensure that ATM operations are compliant with ICAO CNS/ATM plans, provide a seamless service to the user at all times, and operate on the basis of uniformity throughout the ECAC area.
Uniformity embodies both the application of common ATM rules and procedures across all European airspace, and the use of common core technical functionality in the systems used. It is not an all-embracing requirement for identical equipment or systems. Agreed required minimum levels of aircraft equipment, performance and ATM system capabilities will be matched by defined levels of service.

7. Quality
To foster, promote and enhance the use of ISO 9000 or similar recognised quality management standards in the provision of gate-to-gate ATM services.
Quality management systems promote business excellence by ensuring customer satisfaction.

8. Human Involvement and Commitment
To ensure human involvement and commitment to support the change to future ATM, so that operational, technical and support staff can operate effectively, efficiently and safely within their capabilities and obtain challenge and job satisfaction.
ATM systems are expected to remain human-centred for the foreseeable future, and people will play a key role in achieving system safety and capacity enhancements. People are, therefore, an essential element in the ability to deliver ATM services, and their co-operation and involvement in developing and effecting change is essential.

The Target Operational Concept

The target ATM operational concept describes the available operational options, which are expected to be needed to satisfy the strategic objectives. The concept also proposes a new approach and lines of action to achieve the target concept. The lines of action are directions for change, and comprise a series of complementary and stepped operational improvements in the core ATM processes. The operational improvements will need to be progressed in parallel with the on-going modification of airspace control sectors, which is currently the primary method of enhancing capacity. This re-sectorisation of airspace will continue in many areas, either as a means to provide short-term and stand-alone benefits, or as a foundation for other improvements.

The target operational concept embodies a new approach to the way that ATM services are provided in order to obtain network-wide benefits. The principal characteristics and their main advantages are described below.

Flight Management from Gate-to-Gate
Flights will be managed continuously within the ATM network throughout all phases of flight. This will improve planning and reactions to real-time events and make better use of resources, including those at airports.

Enhanced Flexibility and Efficiency
The trajectory of a flight will be managed to reflect the best balance that can be achieved at any moment between the aircraft operators' needs and the prevailing flight or ATM circumstances. This

will enhance the efficiency of both individual flights and total fleet utilisation, while improving the management of traffic.

Collaborative Decision-Making
Decisions will be made by those best positioned to take them, based on the sharing of validated real-time information. This will provide the means for greater efficiencies on a network-wide and individual flight basis. Improved information management will provide a foundation for a dialogue between the various parties in real-time during all phases of flight.

Responsive Capacity Management to Meet Demand
A combination of flexible ATC sectors and capacity management will be applied to ensure that demand can be handled safely and efficiently with minimum delay. This will provide operational and cost efficiencies by allocating resources to satisfy variations in traffic.

Collaborative Airspace Management
A collaborative airspace planning and management mechanism based on the flexible use of airspace, and involving both civil and military authorities will be established. This will ensure that airspace is managed and used as a continuum in a flexible and dynamic way across the whole ECAC region.

Extended Levels of Automation and Communication Support
Future operational improvements will require the support of more sophisticated computer assistance tools and human-machine interfaces able to exploit air/ground data communication, higher quality trajectory prediction data, and the exchange of data between ground units. This will increase ATC productivity and enhance safety nets.

A.5.4 Key concepts and requirements identified

Strategic Actions By Phase Of Flight

This table shows the objectives, the strategic actions needed to support those objectives by phase of flight. The time windows given are approximate and intended to represent progressive implementation.

Phase of Flight	A.5.5 Objective	A.5.6 Strategic Actions	A.5.7 Date
Strategic Planning	• adapt capacity to demand while accommodating cost-benefit considerations	• adaptation of ATC and airports capacity within acceptable safety and environmental limits including airspace planning; • provision of demand data to relevant partners (CFMU and airports); • provision of route options and financial information to airspace users; • provision of the appropriate human and technical resources; • early interaction between service providers, CRCO, airports and airspace users; standardisation of National AIPs; • efficient HMI and tools to access AIS information.	• on-going 2000 to 2015 • 2000-2010 • 2000-2005 • on-going 2000 to 2015 • 2000-2010 • 2000-2005
Pre-tactical planning	• ensure that strategically planned capacity is available to meet needs and provide flexibility to cater for additional or modified airspace user needs.	• provision of adequate human and technical resources to meet the demand on the day of operation; • co-operation between AOs, ATC, ATFM and airport authorities to provide flexibility in managing airport capacity; • efficient access to AIS information.	• on-going 2000 to 2015 • by 2010 • by 2005

Tactical planning	• provide aircraft operators with information that enables them to plan flights for optimum profile / trajectory / route.	• integration of information on capacity constraints at ATCCs and airports to provide optimum airport scheduling information; • integration of ATC and ATFM information together with decision-making tools to provide optimum flight profiles; • enhanced FDP capabilities for ATM and airport ATC to accommodate late flight plan changes; • alignment of tactical Airspace Management (ASM) and Air Traffic Flow Management (ATFM) with ATC to provide capacity where needed; • airspace user access to integrated flight information (AIS, MET, ASM, etc.); measures to prevent system abuse (multiple flight plan filing, etc.).	• 2000-2005 • 2000-2010 • 2000-2010 • 2000-2005 • 2000-2005
Pre-departure	• provide timely data to allow flight crews to prepare optimum flights.	• incorporation of ATFM, airports, AIS, Met, ATS, AOC and aircraft into an interactive and integrated system that provides complete and relevant real-time data; • user-friendly HMI and tools to access the integrated system; • automated co-ordination and decision- making tools to support optimum profile planning. (e.g.: arrival manager, departure manager, etc.).	• 2000-2010 • 2000-2010 • by 2010
Departure -Taxi	• maximise runway utilisation to ensure minimum taxi time and seamless transition between gate and take-off.	• integration of arrival, apron and departure managers; • integration of ATC, ATFM, airports and AOC information; • adequate airport surveillance (A-SMGCS, ASDE) where needed.	• 2000-2010 • by 2010 • by 2012
Departure	• smooth and optimise the transition from take-off to en-route utilising the most efficient profile.	• optimised arrival and departure routes within an agreed environmental policy; • improved availability of real-time flight data from aircraft and AOCs • flight profile prediction and optimisation tools; • conflict resolution tools. • integrated arrival/departure managers at adjacent or close airports; • optimised airport instrumentation for local weather measurement.	• 2000-2005 • 2000-2010 • 2000-2010 • by 2008 • by 2008 • 2000-2005
En-Route	• make the en-route phase of flight a seamless phase of the overall gate-to-gate approach.	• revised institutional policies to facilitate gate-to-gate operations; • inter-related ASM, ATS and ATFM policies and integrated information systems; • compatibility of air and ground systems; • dynamic capacity adjustment; • multi-sector operations and planning tools; • trajectory monitoring tools; • autonomous separation activities in specified areas;	• on-going by 2015 • by 2010 • on-going by 2015 • by 2010 • 2000-2010 • by 2005 • by 2015
Arrival	• maximise runway utilisation and provide a smooth and seamless transition from the en-route to arrival phase using the most efficient profile; • to accommodate different landing priorities for a given operator to optimise hub and spoke operations.	• optimised arrival and departure routes within an agreed environmental policy; • improved availability of real-time flight data from aircraft; • flight profile prediction and optimisation tools; • conflict resolution tools; • integrated arrival/departure managers at adjacent or close airports; • metering and sequencing tools; • commonality of landing aids; • optimised airport instrumentation for local weather measurement.	• by 2005 • by 2010 • by 2005 • by 2008 • by 2008 • by 2008 • by 2010 • by 2008
Arrival -Taxi	• ensure minimum taxi-time and a smooth transition between the runway and gate.	• integration of arrival, apron and departure managers; • integration of ATC, ATFM, airports and AOC information; • adequate airport surveillance (SMGCS,	• by 2015 • by 2012 • by 2012

		ASDE) where needed.	
Post Flight	• provide a single authoritative source of data on completed flights; • provide an efficient and consistent charging system at the lowest possible cost.	• single networked flight data base for archived flight plans, and modifications based on actual events; • integrated charging system.	• by 2005 • by 2008

Changing Roles and Responsibilities

NOTE: Roles and responsibilities are far more extended and complex than indicated below. This table aims to highlight some of the key evolutions through time and is intended to focus attention on the humans responsible for flight and ATM operations on a daily basis.

Period	**A.5.8 Pilot**	**A.5.9 Controller**	**A.5.10 Aircraft Operators**
Up to 2005	**responsible for:** • conduct of flight and instigating changes to plan; **in an environment with:** • navigation based RNAV systems; • greater choice of flight trajectory available on free routes in upper airspace for suitably equipped aircraft; • RT used as main communications with controller and initial/air ground data link applications; • improved cockpit HMI with some automated inputs into FMS.	**responsible for:** • separating aircraft; • a defined fixed airspace sector; **in an environment with:** • a largely unchanged control team; • some tasks (co-ordination & transfer automated); • RT as main communications means with pilot, but initial air/ground data link applications; • electronic flight strips in many units. • increasing reliance on computer tools for monitoring and alerting; • growing emphasis on de-confliction planning; • arrival manager for sequencing aircraft at major airports.	**responsible for:** • pre-planning of flights; **in an environment with:** • some automated links with CFMU, Met. and AIS; • more choice on re-routings; • early CDM operations.
Up to 2010	**responsible for:** • conduct of flight and negotiating changes to trajectory with the ground controller, in some instances in conjunction with Aircraft Operations Centre (AOC); • separation in some defined circumstances (climb, same-way routes) in suitably equipped aircraft; **in an environment with:** • less reliance on RT and many routine messages are exchanged via data link; • greater reliance on 4D flight trajectories and navigation techniques using satellite systems; • integrated FMS with route change inputs automated on many aircraft; • early introduction of ASAS capabilities with improved situational awareness displays on some aircraft; • greater reliance on cockpit systems for airport surface movement.	**responsible for:** • separating aircraft except in limited and defined circumstances; • defined airspace sector but boundaries are subject to change to reflect traffic patterns; **in an environment with:** • progressive emphasis on planning rather than tactical intervention • less reliance on RT and many routine messages exchanged via data link; • most inter-unit data exchange automated, and electronic flight strips at most ATC units; • growing reliance on planning tools and computer generated resolution advice; • controller relying on automated slot sequencing for arrivals and departures at most major airports.	**responsible for:** • pre-planning of flights and diversions; **involved in:** • route choices and in-flight trajectory changes; • some operators: direct negotiation with ATC and aircraft on dynamic route and timings changes. **in an environment with:** • automated links with CFMU, AIS, Met. ATC and airports.

Up to 2015	**responsible for:** • conduct of flight and negotiating changes to trajectory in conjunction with AOC; • maintaining own separation in designated free route airspace using ASAS; **in an environment with:** • routine messages passed by data link with much reduced use of RT; • most trajectory monitoring and change automated within FMS; • automated systems used for airport surface movement.	**responsible for:** • separating aircraft in managed airspace; • managing the organisation of traffic to ensure a smooth flow, particularly in border areas between free and managed airspace; **in an environment with:** • emphasis on automated medium-term planning over a number of sectors and monitoring of de-conflicted trajectories; • routine messages passed by data link with much reduced use of RT; • controller relying on automated slot sequencing for arrivals and departures at major airports.	**responsible for:** • pre-planning of flights and diversions; **involved in:** • direct negotiation with ATC and aircraft on dynamic route and timing changes; • changes to aircraft landing and take-off times negotiated directly with ATC, CFMU and airports. **in an environment with:** • automated down-linking of flight parameters from aircraft in-flight and dynamic optimisation of trajectories passed directly to aircraft..

A.6 AVENUE

A.6.1 Objectives

Validation within the ATM domain is one of the most demanding roles within the overall validation field. When validating new concepts and features for ATM it is necessary to conduct both simulations and real-world demonstrations of the envisaged concepts and system components, with various degrees of integration into a real environment. Due to the scale of the validation exercises generally associated with ATM, it is paramount to ensure the validation's aims are clearly defined; the required ATM components are integrated and fully functioning in a system which is representative of an operational ATM system, robust enough to handle large scale demonstrations and flexible enough to permit evolution of components.

AVENUE is one of the cornerstones between the 4th and 5th FP. It is a part of this "validation service". The AVENUE (an ATM Validation Environment for Use towards EATMS) project is developing, using already validated inputs from ECARDA, Eurocontrol and national projects through Europe, <u>a full validation platform</u> which will be extended and use for validation experiments in the 5th FP programme concerning:

- operational concepts,
- operational requirements,
- standards,
- pre-operational prototypes,
- Industrialisation of components.

The AVENUE platform shall be used to validate whether ATM sub-systems can be integrated into a target operational ATM system. This validation on the AVENUE platform shall be last stage preliminary to their validation on site by industry and air traffic control centres. The platform shall be capable of integrating any potentially representative ATM components: it shall be an open, flexible and modular environment, which enables evolution, integration, interoperability and growth.

The AVENUE Platform is the structure in which all the components are put together and which offers a set of validation services (data preparation, test preparation, supervision, configuration management, recording, data analysis) with the following characteristics:

- easy configuration to support integration of other components,
- flexibility allowing integration of future components,
- easy/simple dissemination to a wide variety of validation sites,
- flexibility allowing evolution and local adaptations.

In consequence, the main objectives of the AVENUE project are:

- the provision of a system architecture of a validation platform capable of supporting the large-scale demonstration and validation initiatives of the European Commission, Eurocontrol and all others concerned with validation of the EATMS.
- the provision of the first instance of that platform, hosted at the Eurocontrol Experimental Centre's Brétigny facility, with a set of adapted components implementing the defined architecture based upon a selection of CNS/ATM components representative of the state of the art developments in Europe.

The components used in the first instance are existing components provided by the partners and which are adapted to the architecture (and not the contrary). These components are mostly ground systems and include elements of data link and simulated airborne components.

A.6.2 Methods used

The project has been divided into 5 phases:

- The conduct of a validation platform requirements capture,
- The specification and system architecture of the platform,
- The adaptation of selected ATM components,
- The integration on to the platform,
- The demonstration of the developed facility's suitability for use as an EATMS validation platform.

The approach adopted involves the definition of a system architecture that will define a comprehensive set of Application Programming Interfaces (APIs) and will provide the standards for integration. It is intended that the selected components will be adapted to these interfaces.

The methodology to define the system architecture is as follows:

- Definition of the logical model that provides the scope, the logical organisation and granularity.
- Specification of a common Data Dictionary and a comprehensive set of APIs that standardise the inter-relation between "the logical components".
- Definition of the technical infrastructure, independent of the middleware.
- Mapping of the pre-selected CNS/ATM components onto the "logical components", that define the generic functionality and scope of each "physical component".
- Specification of the components interface definition and Model of Execution that detail the role and responsibilities of each "physical component" in the AVENUE platform 1st instance, along with the dependencies between all of them.
- Implementation of the technical infrastructure that hosts the physical components.

Industry standard CORBA technology using technical services from the PATIO unified architecture and Eurocontrol's OASIS (evolution of the CORBA system that is available in-house at the EEC) has been selected by EC as the middleware foundation for the platform.

The architecture is based on the Component model CORBA3. Each component will be encapsulated in a container that isolates it from the other components and from the middleware. A component can interact with the other components using a very pure level view of them: those abstract views constitute the AVENUE APIs, defining the services that the component can provide. These API are described in the formal language IDL3. All the technical details, such as how to locate the other components, are isolated from the component and managed at the container level. The APIs refer to a Data Dictionary. So far 250 services and 125 events have been defined.

The adoption of a component/container model with APIs contribute to the flexibility of the platform, due to the high level of encapsulation and abstraction provided by the APIs. It is of paramount importance that the API specifications are defined without reference to both the components and the middleware technology.

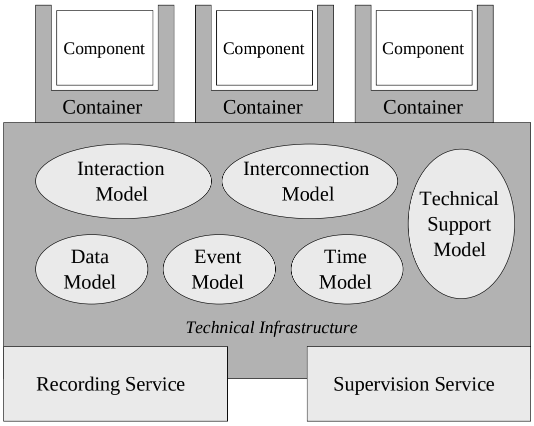


Figure 1 - AVENUE Component / Container model

A.6.3 Main results

This project, as part of the 4FP, has begun in February 98 and will end in March 2001. In the 5FP, the platform will be enriched by up coming en route tools and expended with TMA tools and SMGCS, connection to real aircraft to allow the gate-to-gate validations.

- The requirements phase is complete.
- The architecture of the platform is achieved.
- A set of API has been defined (September 99).
- The system infrastructure design is complete.
- The physical architecture will be achieved in May 2000. The adaptation work is on going. The integration of components will begin in June 00 and the demonstration will begin in early 2001. The project will end in March 2001 (initially planned September 2000)

A set of components has been currently selected which will be integrated to form the platform at Brétigny. These components have been chosen to represent a comprehensive set of the ATM facilities considered necessary for validating future EATMS concepts. This will include elements of data link and simulated airborne components. This set of selected components is based on the results of several existing activities (see figure below).

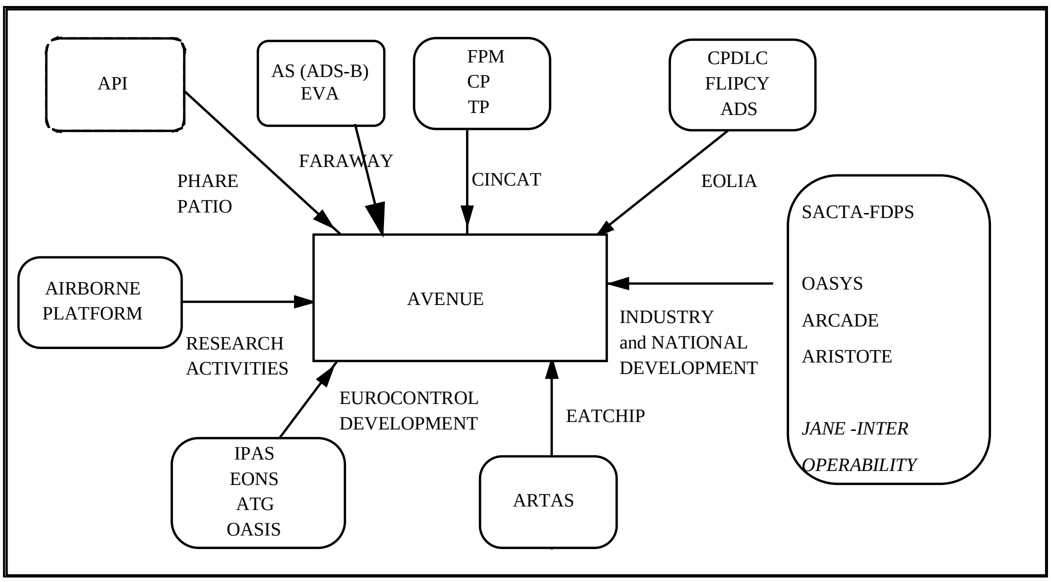


Figure 2 - Components integrated within AVENUE

The components will be adapted and integrated in the first instance of the AVENUE platform at Brétigny. The following table provides their details.

Component Identifier	**Providing Partner**	**Function**
ADSB		ADS broadcast surveillance data processing.
ARCADES	ALCATEL	Data recording
ARISTOTE	ALCATEL	Data analysis off-line
ARTAS	EEC	Multi-Radar data processing
ASAS		Airborne Separation assurance
CINCAT/CP	AATM	Conflict probe
CINCAT/FPM	NLR	Flight path monitor
CINCAT/TP	AATM	Trajectory predictor
Data Fusion	ALENIA	Data fusion of Radar tracks and ADSB tracks.
ECS		External multi-cockpit simulator
EOLIA	AATM/SOF	Ground part of the air/ground data link applications: DLIC, CIC, ACM, ADS-C and air-ground flight plan consistency (FLIPCY).
EONS	EEC	Controller working position
EVA	ALENIA	Analysis off-line of track data
IPAS	EEC	Data preparation off-line
JANE interoperability	DFS	Interoperation between AVENUE and JANE platforms.
MASS		Air traffic generator
OASYS/TMCS	AATM	Technical supervision
Radar Emulator		Emulator of Radar from MASS air traffic data
SACTA/FDPS	AENA/INDRA	Flight Data processing and distribution, including the on-line data servers.
SIMINGA	SOF	Simulators interconnection

Table 1 - Selected components for AVENUE 1st instance platform

The following picture presents the preliminary architecture of the system in terms of processors and workstations. The information flows marked ①...④ comprise the following: ①=Centre-Centre-Co-ordination messages, ②=air-ground data communication messages, ③=ADS-B info of simulated aircraft, ④=radar plot messages.

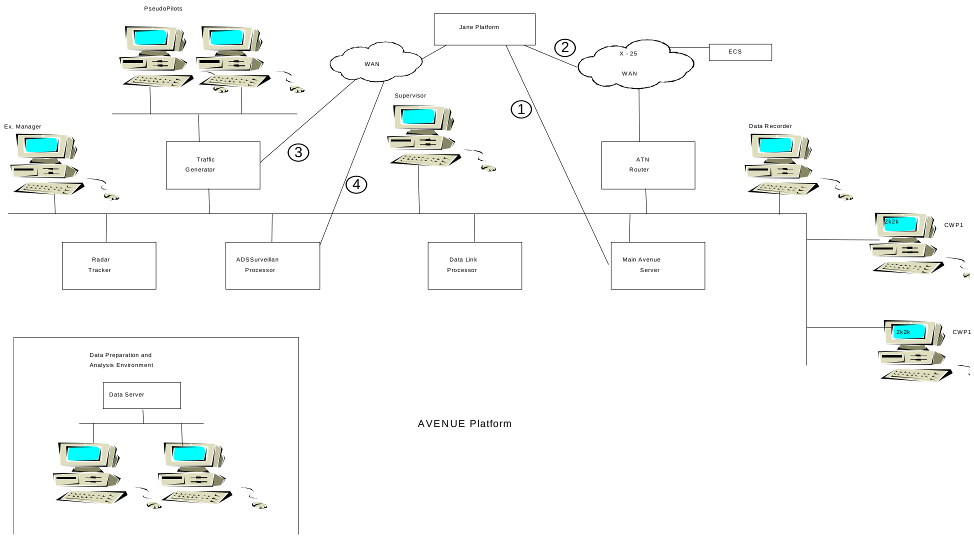


Figure 3 - AVENUE hardware architecture

A.6.4 Key Concepts and Requirements Identified

In AVENUE, there are not privileged key concepts, requirements, or technologies, regarding ATM. That is because the AVENUE platform is aimed to be open, flexible, and capable of supporting any European ATM system. Even if the first instance of the platform will be based on components derived from specific ATM concepts and technologies, the platform will be able to integrate any new component.

The AVENUE validation platform will be, for any new tool, the means whereby a new range of integration approaches will be investigated and the tools pre-operationally validated in large-scale real time simulations.

More precisely, the project will offer:

- a methodology to define standard interfaces and to allow the integration of a new component,
- a commonly agreed architecture including a set of de-facto standardised industrial interfaces, which permit the exchange of components at a software level between the partners and direct comparison of results,
- an instance of the platform allowing early validations.

The collaboration between the European partners to produce a common flexibility configurable platform will enable these essential validation activities to be readily set up and the results from different validation exercises to be directly compared. This will greatly reduce the time required to gain acceptance for a new tool on a European rather than an individual civil aviation authority basis.
The System architecture, the Interfaces description (APIs), the platform user manual will be made available for the public domain.

The adapted components implementing the defined architecture will be disseminated to each partner who requests them through appropriate arrangements. In other terms, the first instance of the platform hosted in Eurocontrol Experimental Centre will be disseminated to the partners for each partner need, allowing any validation.

In the precise case of the AFAS and MA-AFAS projects, the AVENUE platform (first instance, as available by mid 2001) is planned to take part in an end-to-end integration with the airborne segment developed by both projects.

A.7 Capstone (FAA Alaska Region)

A.7.1 Introduction

Flight 2000 was an initiative to deploy and evaluate selected planned air traffic management systems for implementation by the year 2005 in the National Air Space (NAS). The objectives of the program were to:

a) demonstrate safety and efficiency benefits of new technology,
b) demonstrate improved procedures,
c) evaluate communication, navigation, and surveillance (CNS) transition issues,
d) streamline avionics development, certification, and installation, and
e) reduce the risks in an accelerated NAS modernisation programme

These integrated demonstrations and validation activities should have begun in September 2000. However, the initiative was too encompassing, too expensive and lacked stakeholder buy-in. Industry's RTCA Select Committee on Free Flight has now endorsed a revised, less ambitious approach, documented in the FFOEP. Most Flight 2000 Program activities originally planned to occur in Alaska are included in the new roadmap.

Within the Alaskan Region, Flight 2000 served as the "capstone" for many additional initiatives, providing a common umbrella for planning, co-ordination, focus, and direction with regard to development of the future NAS. A few additional "technology-driven" initiatives supportive of Flight 2000 are recommended in a March, 1995 NTSB Alaska Safety Study, however, the success of each is inextricably linked to success for the other. As an example, the additional aviation weather observing systems the NTSB called for in Alaska relies on the Flight 2000 Flight Information System (FIS) element to provide the information developed via data link to the pilot.

The Capstone Program was created to address Alaska's high accident rate for small aircraft. Capstone is an accelerated effort to improve aviation safety and efficiency through installation of cost-effective, new equipment in most commercial aircraft serving a delta area in Alaska. The equipment consists of government-furnished Global Positioning System (GPS)-based avionics and data link communications suites. Compatible ground systems, equipment, and services will also be provided. Aircraft operator participation in the Capstone Program is voluntary.

Some Capstone-equipped aircraft and the Capstone ground system infrastructure have been used beginning in January, 2000 to validate three of the nine high priority Free Flight Operational Enhancements of Table 1. Operational enhancements included in Project Capstone are:

a) Flight Information System for Special Use Airspace, Weather, Windshear, NOTAMS, and Pilot Reports,
b) Cost Effective Controlled Flight into Terrain Avoidance through Graphical Position Display, and
c) Enhanced See and Avoid.

Validation of other operational enhancements will be undertaken in future years.

The initial safety improvements and services of the Capstone Program are directed toward pilots operating under visual flight rules (VFR). In the future, FAA plans to certify systems and equipment and develop enhanced operational procedures for instrument flight rule (IFR) operations. FAA anticipates that the operational enhancements and flight efficiencies offered by this new technology will encourage other owners to self-equip their aircraft.

FAA strategy is to encourage voluntary avionics equipage by supporting early highly-beneficial capabilities. One aspect of this is early selection of a long-term link decision for ADS-B, which is a prerequisite for implementation beyond Safe Flight 21.

The table below shows the scale of the deployment:

Category	Cost	Comments
Aircraft Equipment GPS, ADS, FIS, Terrain Information	$4.0 M	200 aircraft
Communications, Radio Links, Digital voice and data	$1.2M	12 locations
Automation, Software, Gateway for Radar Processor	$3.1M	Micro-EARTS software
FIS	$500K	Server, Software, Weather
Training, Aircrew(Users), Acft Maintenance, AF Maint, Operators	$500K	UAA Procedure development & Eval Operator - Familiarization Tng Human Factors
Tech Support/MISC	$1M	
Automated Weather Observing	$1M/	Some of the 49 additional airports
SATCOM		Currently Funded
WIC		Currently Funded
Airports, Approaches, Airspace		Currently Funded
Totals	$11.3M	

Table 2: Capstone Program Requirements FY 99

A.7.2 Objectives

The Capstone initiative is intended to be a visible program to provide tangible benefits. A key objective of Flight 2000 had been to accelerate implementation and use of modern technology. Early deployment is intended by Capstone, in order to have a positive effect on safety, create an infrastructure to permit initial procedures development, familiarise flight crews, controllers, and avionics installers with modern equipment and concepts, and address certification issues and procedures prior to the actual start of the FFOEP evaluation.

The principal objective of the Capstone Program is to improve the pilot's situational awareness of the flight environment. An on-board terrain database will be integrated with a GPS-based moving map display so that the pilot can quickly identify the aircraft's position and the location of hazardous terrain; Automatic dependent surveillance-broadcast (ADS-B) service is intended to enable each participating aircraft to broadcast its GPS-derived position and other information once each second and to receive similar signals broadcast from other aircraft. These ADS-B targets are then presented on the cockpit multi-function display (MFD) so that the pilot will be informed of the identification, position, altitude, climb rate, and flight vector (direction) of other nearby aircraft and can identify any potential threats to the planned route of flight. In the future, radar targets of non-participating aircraft will also be relayed from ground stations to the aircraft for display on the MFD (TIS-B). During the Capstone Program, flight information services (FIS) will also be provided to the pilot in the form of text messages and graphical information on the MFD. FIS will include weather reports, forecasts, and maps, status of special use airspace, pilot reports, and notices to aviators.

The FFEOP provides for field evaluation of alternative ADS-B technologies, thus any ADS technology fielded under Capstone is interim and will be replaced. It is considered that the benefits from early procedure development and integration activities along with immediate safety enhancements cancel any saving from further delay in fielding this technology.

A.7.3 Methods Used

Capstone is a large project, the bulk of which is a large-scale flight trial. Aircraft selected for the trial will receive:

- An IFR-certified GPS navigation receiver
- ADS-B Transmitter/Receiver
- A moving map display with TIS-B traffic and terrain advisory services
- FIS providing weather maps, special use airspace status, wind shear alerts, NOTAMs, and PIREPs
- A multi-function colour display.

Under the Capstone Program, the Alaskan Region's Flight Procedure's Office will request development of a first-time GPS-based non-precision instrument approach to one or more runways. In anticipation of this, 10 airports have been GPS-surveyed. To conduct instrument approaches under FAR Part 121 or 135, weather reporting is essential. These same airports are slated to receive automated weather reporting equipment during the Capstone program.

A.7.4 Main Results of Project

A.7.4.1 Demonstrations

- Display of ADS-B aircraft position reports for controllers at the Anchorage Air Route Traffic Control Center (ARTCC) was demonstrated in May 1999.
- UPS Aviation Technologies (UPS AT), a subsidiary of United Parcel Service, demonstrated the proposed Capstone avionics equipment to the Federal Aviation Administration and local commercial operators on August 24th and 25th, 1999.
- Using a General Aviation aircraft and a further, specially equipped light aircraft, UPS AT demonstrated that its proposed GPS navigation unit, multi-function cockpit display (MFD) and datalink would meet FAA performance specifications for the Capstone Program. The MA-AFAS program should endeavour to obtain these performance specifications.
- Following the flight demonstration and subsequent data review, the FAA awarded a contract to UPS AT on September 13, 1999 to supply avionics and ground-based transceivers for the Capstone program.

A.7.4.2 Short Term Progress

- Installation: 75 suites delivered, 25 installations completed. Provisioning supplementary type certificate (STC) has been awarded for this installation.
- Pilot training is taking place. Users meetings have been held. Consideration is now being given to the installation of an enhanced ground proximity warning capability in small general aviation aircraft. There have been difficulties observed in setting the 24-bit address required for ADS-B equipment.
- In late April 2000, the GPS nav/comm, multifunction display, moving map, and terrain database were demonstrated.

- Certification: M-EARTS (ground station) processing of ADS-B signals progressing. The Product Team Lead recommends that the Region issue an interim maintenance notice authorising system level Ground Broadcast Transceiver certification. Interim authorisation is necessary because preparation of the final maintenance handbook will take up to a year and M-EARTS IOC and ORD would be delayed.
- More details of results are included in the Annex at the end of this review.

A.7.5 Key Concepts and Requirements Identified in this Project

US analysis has shown that benefits accrue from near-term installation of the equipment listed earlier.

A.7.6 References

1. 1st Quarterly Report, 1st Quarter FY00
2. Capstone Program Newsletter, Feb 1999, March 21, May 2, 2000

A.7.7 Annex: Capstone identified improvements

The FAA Alaskan Region identified the following FFOEP elements and related NTSB safety improvements for limited deployment in FY 1999:

Elements	Airborne Systems;	Ground Systems;
I. FFOEP		
A. Initial Procedures Development		
Equipment certification, installation, approvals, and functional validation	Mixed aircraft types: single piston, multi-piston, turbo-prop (aircraft serving the Bethel hub – approximately 200 total).	12 sites in and around the Bethel hub, plus data communications system and ZAN processing and display equipment setup and functional test (mix of contractor and government provided equipment).
VFR see and avoid and IFR en route air-to-air separation (ADS), traffic information pilot procedures	Initial installation and pilot orientation, functional characteristics baseline and database of equipment performance. Use above aircraft.	Same sites.
IFR in non-radar airspace terminal procedures (ADS).	Initial installation, database of baseline performance. Use above aircraft.	Airspace management evaluation. Additional 3 sites for area navigation evaluation.
B. CFIT Avoidance development.	Mixed aircraft types: single piston, multi-piston, t-prop.	None.
Test procedures development.	Flight test in non-radar areas to develop test procedures.	None.
Terrain data base	Flight test human factors	None.

selection and initial crew use validation.	questionnaire development based on initial trials.	
C. FIS Product Development		
Equipment functional validation.	Diverse locations, altitudes, operations.	Ground simulators at UAA.
Weather product development customized for Alaska: a) Icing b) Ceiling and Visibility	None.	UAA Experimental Forecast Facility equipment (computers) and product development.
Weather product, existing, validation of requirements.	Baseline of operational use of products.	10 additional stations for wide area coverage.
Weather, existing, product verification of accuracy.	Baseline of operational use of product.	Same.
NOTAMs, SUA status	None.	Baseline dissemination capabilities, procedures, operational use.
II. FFOEP-Related Safety Improvements (NTSB Report Response).		
A. Navigation Equipment		
Equipment functional validation	Mixed aircraft types: single piston, multi-piston, turbo-prop. Installation procedures development and documentation.	Selected airports in and around the Bethel hub.
GPS en route navigation.	Operational baseline database.	Airspace action to reduce floor of controlled airspace.
GPS terminal arrival and departure.	Human factors baseline database.	Controller procedure baseline database.
B. Weather Sensing		
Equipment installation, automated weather observation systems.	None.	Begin acquisition of 38 for airports with GPS approaches

A.8 CASCADE

A.8.1 Objectives

CASCADE (Contribution for the Assessment of Common ATM Development in Europe) is a project sponsored by EC's Directorate-General For Transport (DG VII), which is a part of the European Common Approach for R&D in ATM (ECARDA) initiative within the European Union's Fourth Framework Programme for Telematics and Transport. It aims to identify needs, propose solutions for the future, and select the best candidate facilities within the field of ATM systems in Europe for the validation process and to propose solutions for requirements which are not currently fulfilled. The general principle underlying CASCADE is harmonisation, of both the functionality and development process of ATM systems.

CASCADE should produce:

- a set of solutions which can be achieved using available knowledge
- a set of solutions which can be achieved using present studies and development
- Remaining solutions, which will require further research and development.

To reach these objectives the project has been divided in three work packages:

- **WP1, Survey of current ATM facilities**: The goal of WP1 is to get an extensive view on validation means and technique related to current ATM, either already existing or under development. This WP is achieved and its results are presented in CASCADE TN1 and TN2 (Ref. 1, Ref. 2).

- **WP2, Comparison between existing and needed facilities**: This WP aims at demonstrating capability of the available means identified in WP1 to perform the validation process and identifying the needed complementary elements.
  The results of this WP were presented in two Technical Notes representing the output of WP2.1 "Cross Mapping" and WP2.2 "Facility compliance assessment".

- **WP3, Recommended solutions**: The aim of this WP is to propose solutions to provide the complementary elements identified in WP2.

The partners involved in this project were: AEROSPATIALE, ALENIA, SWEDAVIA, INDRA-DTD and AENA.

A.8.2 Methods used

It was based in the developing of two Databases, the existing validation facilities Database and needed validation facilities the Database.

The "existing validation facilities database" is built starting from the description of the European ATM assessment facilities performed in CASCADE WP 1.

The "needed validation facilities database" had to be built using the information provided by the two EC's projects GENOVA and ASIVAL which expected results was:

- ATM functional breakdown;
- ATM validation needs.

The use of the cross mapping method allows selection of new and existing tools, covering the basic functional requirements of the ATM systems. The scope is to obtain the optimal (in terms of cost) set of tools.

The cross mapping methodology consists of the following steps:

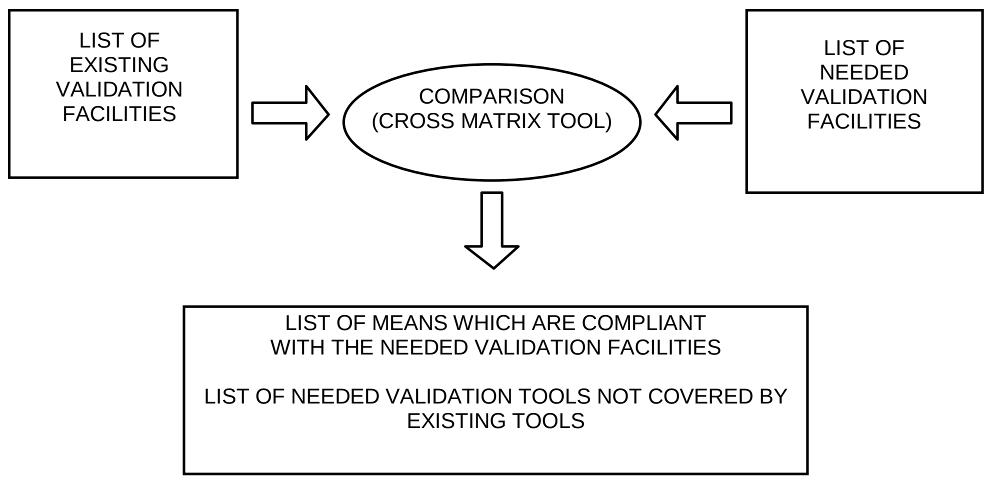
1. Classification of the existing validation tools according to the ATM. In this step all the existing validation facilities are collected in a database with an appropriate form.
2. Classification of the needed validation facilities.

   The needed validation facilities have to be identified and classified according to the ATM breakdown described. To perform this task each partner has to provide one or more examples of ATM system from which some needs for validation will be extracted. In addition, other needs can be obtained by studies addressing validation needs.

   When these needs for validation will be defined, they will be collected in a new database, using the same form of the one for the existing validation facilities.
3. Development of a cross mapping tool to compare the existing and the needed validation facilities databases.

A cross mapping tool has been developed to compare easily the two databases. By this tool it is possible to identify a tool that fulfil with specific needs for validation. Moreover, the tool also allows to find the non-existing complementary facilities required to perform the system validation.

The following figure showing a scheme of the process



Comparison between existing and needed facilities

The main objective of Cross mapping is to establish what are all the validation tools needed to cope with all the needs for validation deriving from the use of the new ATM systems.

To perform this task, it was necessary to get the needs for validation to compare with the existing validation tool. In this way it is possible to obtain either what are the existing tools to validate a specific need or what are the needs for validation not yet covered by the tools.

In CASCADE project the needs for validation had to be provided by other studies (GENOVA and ASIVAL projects), but because the lack of information from GENOVA, the CASCADE team decides to provide itself some of these needs extracting them from specific examples of ATM systems.

A.8.3 Main Results

As the aim of this study was to assess to which extent some methods or tools developed in the frame of other Programs could be used for validating EATMS, three systems were analysed. Those systems were quite different from each other from a technical point of view and from a development status point of view as well.

The various tools and facilities surveyed were designed and developed in close relationship with the design of the system they aim at validating. Consequently, it appears that their use for EATMS validation purpose could be hardly envisaged from a technical point of view.

Furthermore, considering confidentiality and working load aspects, authorisation of use should be a question not easy to deal with.

Nevertheless, if the use of those external facilities doesn't seem possible, EATMS could take advantage from the philosophy and methodology they are based on. In this regard, the outstanding features that should be of interest in the field of EATMS validation are the following ones.

- Validation and verification V method
- System breakdown into subsystems
- Validation/verification platform at system level
- Philosophy used for the Air Force Command and Control System test and validation facility
- Methodology used for EGNOS (European Geo-stationary Navigation Overlay satellite System) validation and verification Platforms.

A.8.4 Key Concepts and Requirements Identified

The results of the different Work package about the present survey of the existing facilities for validation of ATM systems in Europe shows the following key concepts:

* One of the input of the cross mapping tool is a database containing all the information about all the existing validation facilities.
* This information will be compared with the same information related to the needs for validation collected in the second database.
* To make possible this comparison, checking on the simile fields, the two databases must have a common form in which to store the information.
* For the development of the Cross-Mapping Tool a survey of the major database development environment was performed, and the main candidates were Microsoft ACCESS, DB IV, ORACLE and SQL. The chosen was been Microsoft ACCESS for various reasons; among which the use of the SQL and the possibility to create a friendly GUI (Graphical User Interface).
* The structure of Cross Mapping Tool is strictly linked with the specification of SQL and it contained:
    - Two tables representing the databases of existing facilities and validation needs;
    - A set of query used to perform the cross mapping;
    - A set of Graphical User Interface to facilitate the navigation in Cross Mapping Tool and for the presentation of results.
* The database was developed taking into account the ATM breakdown. In this ATM breakdown we can find a set of *groups* representing the main categories in which ATM system is split; each group was subdivided in *components* that contain a variable set of *functional elements*.

The following Key requirements for the Assessment of common ATM Development were identified:

* The very beginning of the quality process should consist of the analysis of current systems, their shortcomings and possible enhancements (which will constitute future Requirements). In Europe, this was made in a harmonised way, and the Agency EUROCONTROL is awarded to do this. The Convergence and Implementation Programme was the technique developed by the Agency to regularly monitor the accomplishment of harmonisation plans. However, it could be completed by the in-depth knowledge of current systems, and through a systematic analysis of them.
* With the existent test means, the overall process of validation can be covered for ATM systems. Some of the validation steps were, however, better maturely achieved.
* Analysis of Requirements for validation and for preliminary design was not very maturely developed in a computer-support level. Techniques followed in present for Requirements Analysis were conceptual rather than physical. Some CASE tools exist or were being developed, but their implementation in quality processes was not yet generalised.
* Hardware and Software tests facilities were mainly used to perform trials when systems are being built in factory, and for validation of the final product by users.
* Aircraft is the most advanced segment in relation with coherent, integrated quality processes in Europe. The existence of common standards facilitates the certification of Avionics and other aircraft equipment. The same cannot be said for Ground ATM systems, for which independent tests are performed during quality process, according with specific design of the systems, local needs, etc.
* Connectivity between different test means (for testing different ATM parts) was not considered. Interfaces were simulated *in situ* by creating, for instance, radar and flight plan exercises prepared *ad-hoc.* End-to-end trials were also performed by simulating the whole system at unique laboratory site. Exception is made for communication trials (e.g. implementation of new OLDI lines), in which both units were involved, and co-ordination between centres was carried out.
* The Test facilities of Space Segment came from the Aerospatiale Industry because is the most recent technology used for ATM. These test facilities came from the Aerospatiale Industry, but specific means have to be provided for ATM applications.
* Commonalty aspects do exist with respect to EATMS features, but the various tools and facilities surveyed were designed and developed in close relationship with the design of the system they aim at validating. Consequently, it appears that their use for EATMS validation purpose could be hardly envisaged from a technical point of view.

A.9 CDM

A.9.1 Objectives

The project aims to identify possible specific applications of the concept of Collaborative Decision Making (CDM) within the context of EATMS, and to develop those applications in order to assess, qualitatively, their potential costs and benefits.

The project also aims to identify areas where research and development will be needed to validate the applications and their foreseen benefits. This is intended to allow future research and development priorities to be determined. The project does not attempt to prioritise or rank the applications.

Several of the applications are not new and are included in existing programmes: their inclusion merely serves to demonstrate that CDM already exists in many places in the ATM system.

The purpose of the project is to identify possible specific applications of CDM as a means of elaborating the concept of CDM. Thus it is not intended to define a “CDM programme”. Rather, it is proposed that the potential applications could be considered in any of the following ways (as appropriate to the application):

- by clear recognition of the application of the concept where it exists within current Eurocontrol programmes;
- by initiation of a dedicated Eurocontrol programme where applications are of sufficient scope and complexity to merit this, and where the development activity is definable as a separate activity independent of other programmes and with clear deliverables and timescale;
- by standalone development projects linked to activities of individual states of airports where an application is directed at localised changes in operational procedures rather than in a European-wide initiative.

An application of CDM is defined to be one that aims to improving flight operations through the increased involvement of Airlines’ Operations Centres (AOC) and of Airport Operations in the process of Air Traffic Management (ATM). This covers applications aiming to take into account the internal priorities of the AOC or the Airport, before and during the flight, and development of Information Management systems and procedures in order to make full use of available data.

Essentially, this includes two kinds of collaboration, which can be summarised as follows:
- an area where improved exchange of up-to-date information, involving ATM, Aircraft Operators (AO) and/or Airport Authorities (AA), will significantly help to improve the efficiency of an existing process (either overall, or for one or more actors);
- a new collaborative process in which actors exchange information on the constraints which affect their planning, and/or where decisions are delegated to the actor best-placed to take them.

A.9.2 Methods used

The project employed two different approaches in identifying potential applications of CDM.

Firstly, the project team performed a walk-through of the EATMS “gate-to-gate” flight phases, carefully considering the interfaces between the phases, to identify areas where there is potential for collaboration. In other words to identify areas where improved information exchange between actors, or increased involvement of new actors in a decision-making process, could improve flight operations. The main characteristics of the EATMS OCD were kept in focus throughout this walk-through.

Secondly, the conclusions of the FASTER project were reviewed. The FASTER project interviewed Aircraft Operators, Airport Authorities and ATM service providers (both Area and Aerodrome control) to understand what information they currently use, and how their operations could be improved by better co-operative sharing of information. This, together with other aspects of the project team's experience, ensures that the applications described are focused on the requirements of the operations staff from all parties involved in the management of air traffic.

A.9.3 Main results

Twenty-two potential applications of Collaborative Decision-Making have been identified. All the potential applications identified are described. The applications that have been developed by the project are presented in the following format:

1. **General description** – describes the context for the application by reference to the current ATM system and its perceived shortcomings, and outlines the proposed changes;
2. **Description of the process** – describes the process in more detail, defining which actors would be involved and their responsibilities, the information flows required, and the process steps (where appropriate);
3. **ATM 2000+ timescale** – notes where the application fits in with the timescale for changes proposed for in the ATM Strategy for 2000+ Road-map of Change;
4. **Evaluation of costs and benefits** – notes foreseen areas of cost and benefit, and to which actors these would accrue, and comments on how they might be measured;
5. **Dependencies** – identifies pre-requisites for implementation of the application;
6. **Problems and studies needed** – highlights issues that would need to be considered in the further development of the application, and areas where research and development or further study is required.

The study team has identified and explored twenty-two potential applications of CDM ideas and principles. To provide an overview, the applications have been summarised in tables in terms of short, medium and long term based on the timescale proposed in [ATM2000+], and a summary of potential benefits, involved actors and the planning horizon of each is provided.

Applications Proposed for Implementation in the Short Term
(approx. 2000–2002, following [ATM2000+] timescales)

Applications (report section no.)	A.9.3.1 Potential Benefits	A.9.3.2 Involved Actors	A.9.3.3 Flight Operations / ATM Planning Layer
Conditional Routes in Flight Planning (5.1)	• Increased use of CDRs in flight planning • Reduced fuel costs • Capacity increase	• AOC, CFMU, AMC	• Flight Planning / Pre-tactical and Tactical Flow Management

Re-routing (6.4)	• Reduced ATFM delays • Increased flexibility for airspace users • Reduced likelihood of ATC sector overloads	• AOC, CFMU	• Flight Planning / Pre-tactical and Tactical Flow Management
Slot Swapping (6.5)	• Possibility for Aircraft Operators to prioritise flights within their own set of flights	• AOC, CFMU	• Flight Planning / Pre-tactical and Tactical Flow Management
Airport Information for Flight Planning (6.8)	• Minimisation of the loaded fuel • Improvement of the flight trajectory prediction	• AOC, ATC at departure airport, ATC at arrival airport, CFMU	• Operations Control / ATC Planning
Estimation of In-Block Time (7.3)	• Improvement of the stand allocation process • Better utilisation of the ground facilities • Improved operations for the airlines • Shared understanding of Estimated Time of Arrival	• AOC, ATC (APP, Tower, Ground Control), Airport Authorities, AOC	• Operations Control / ATC Planning
Meteo Information Exchange (7.7)	• Greatly increased quantity of observations for meteo modelling and forecasting • Enables significant improvement in quality of meteo information available to airspace users and service providers	• [Sources are **Flight Deck** and Meteo Service Providers]	• Flight Management / Tactical ATC
Estimation of Departure Time (8.2)	• Updated estimates of departure time for Stand Allocation, AOC, ACC • More effective planning of departing flights	• CFMU, ATC (DEP, ACC, ARR), AOC, Stand Allocation Units	• Operations Control / ATC Planning
Information About Disruption (8.5)	• Better-informed decisions by Aircraft Operators in cases of disruption • Should reduce disruption to schedules • Better and safer use of available ATC and Airport capacity	• Meteo Service Providers, Airport ATC, Airport Authorities, ATC Units (ACC or FMP), CFMU, AOC	• Operations Control / ATC Planning

Applications Proposed for Implementation in the Medium Term (approx. 2003–2007, following [ATM2000+] timescales)

Applications (report section no.)	A.9.3.4 Potential Benefits	A.9.3.5 Involved Actors	A.9.3.6 Flight Operations / ATM.Planning Layer
Traffic Planning Model (6.2)	• Better quality predictions of traffic for ATM operations management	• CFMU, AOC, National System, Airports, Booking Systems, FMP	• Fleet planning & Schedule planning, Flight Planning / Strategic management of airspace and traffic flows, Pre-tactical and Tactical Flow Management
Substitution on Cancellation (6.6)	• Better use of airport capacity in situations of congestion • Improved fleet management for Aircraft Operators • Enhanced traffic flow management and disruption recovery	• AOC, CFMU, FMP	• Flight planning / Pre-tactical and Tactical Flow Management
Slot Shifting (6.7)	• Reduction in lost ATFM slots • Better use of airport ground infrastructures • More flexibility for the airlines • Reduced use of slot extension process	• AOC, **Pilot**, Station Manager, CFMU, ATC of Departure Airport	• Flight planning / Pre-tactical and Tactical Flow Management
Distribution of AO/Aircraft Flight Plan Information (7.1)	• Updated flight plan information available • Improves trajectory predictions by ATC and ATFM	• [AOC, ATC]	• Operations Control / ATC Planning
Collaborative Stand and Gate Management (8.1)	• More efficient management of stands and gates • Increased utilisation of airport resources	• (AOC, Airport ATC, Airport Authorities)	• Operations Control / ATC Planning
Estimation of Off-Block Time (8.3)	• Accurate estimate of Off-Blocks Time made available to all actors • More effective planning of departing flights	• Ground Ops Co-ordinator, Tower ATC, Apron Control, **Pilot**, AOC, Stand Allocation Unit	• Operations Control / ATC Planning

Collaborative Departures Sequencing (8.4)	• Aircraft Operator and Airport priorities taken into account in departures sequence • Increased flexibility and more efficient operations for Aircraft Operator • Increased utilisation of airport resources	• **Pilot**, Departure ATC, Apron Control, Stand Allocation Unit, AOC	• Operations Control / ATC Planning
Disruption Recovery – Departures from Nearby Airfields (8.6)	• Better utilisation of available capacity • Improved disruption recovery	• Local ATC unit, CFMU, AOC, **Pilot**, Departure ATC	• Flight Planning & Operations Control / Pre-tactical and Tactical Flow Management

Applications Proposed for Implementation in the Longer Term (approx. 2008–2015, following [ATM2000+] timescales)

Applications (report section no.)	A.9.3.7 Potential Benefits	A.9.3.8 Involved Actors	A.9.3.9 Flight Operations / ATM Planning Layer
Collaborative Flow and Capacity Management (6.1)	• Optimise match between ATC capacity and traffic demand • Reduced ATFM delays • Reduced likelihood of ATC sector overloads • Increased flexibility for airspace users	• ATC Units, Military Users, CFMU, AOC	• Flight Planning / Pre-tactical and Tactical Flow Management
Co-ordination between Airport Slot and ATFM (6.3)	• Better schedule-keeping • Reduced ATFM delays • Reduced likelihood of ATC sector overloads	• [Airport Authorities, CFMU]	• --- / Pre-tactical and Tactical Flow Management
In-Flight Traffic Management (7.2)	• Improved decision making by Aircraft Operators in the airborne phases of flight	• ATC, AOC, Airport Authorities, **Pilot**, Weather Services, Military Control Centres, CFMU	• Operations Control / ATC Planning
Optimisation of Arrivals (7.4)	• Improved decision making by Aircraft Operators on stacked flights in holding areas • Improved control on changing runway configurations	• ATC (ARR SP, APP TC), Airport Authorities, AOC, **Pilot**	• Operations Control / ATC Planning

Integrated Arrivals and Departures Management (7.5)	• Global optimisation of planning on scheduled departure and arrival times • Ensuring better flight efficiency by integrated arrival management • Optimised use of scarce arrival resources	• AOC, CFMU, Dep ATC, Arr ATC	• Operations Control / ATC Planning
Autonomous Separation in Free Flight Airspace (7.6)	• Increased flexibility and flight efficiency for Aircraft Operators • Reduced ATC workload	• [ATC, **Pilot**]	• Flight Management / Tactical ATC

A.9.4 Key concepts and requirements identified (in the project)

The key concept is collaborative decision making involving Airline Operations Control and Traffic Flow Management and to a somewhat lesser extent ATC, Airport Authorities and the Aircraft. The role and/or information requirements as identified for the aircraft are listed below per CDM application.

A.9.4.1 Short term

- Meteo Information Exchange (7.7) — Pilot reports, particularly concerning sever weather
  Wind and temperature updates from on-board sensors

A.9.4.2 Medium term

- Slot Shifting (6.7)
  1. After co-ordinating with AOC, pilot sends slot revision request to ATC (at departure airport)
  2. ATC relays request to CFMU
  3. CFMU sends new CTOT, EOBT to ATC
  4. ATC relays new EOBT, CTOT to the pilot
  5. Pilot accepts, and relays new EOBT, CTOT to AOC
  6. ATC relays acceptance to CFMU
  7. CFMU updates FPL and sends it to all concerned
- Estimation of Off-Block Time (8.3) — Pilot is responsible for maintaining an estimate of the time at which he will be ready for start-up (using information from the ground ops co-ordinator), and passing this to ATC at least an agreed time in advance of the call for start-up. He should also pass updates to that estimate as appropriate, for example as a problem which results in a delay is discovered or solved.
- Collaborative Departures Sequencing (8.4) — The pilot is responsible for passing ATC an estimate of the time at which his flight will be ready to start-up (as in 8.3).
- Disruption Recovery – Departures from Nearby Airfields (8.6) — Pilots would be responsible (as now) for indicating that they are ready to depart. AOC would be responsible for re-planning their flights as necessary, and ensuring their pilots are aware of the situation.

A.9.4.3 Longer term

• in-flight Traffic Management (7.2)	Reasons for re-planning include to optimise towards optimal flight scheduling, to avoid congestion, to free routing options, arrival capacity at destination airport, to avoid unfavourable weather, and at pilot's request. Pilots will participate in AOC re-planning activities and if the pilot needs a flight plan change within the short-term implementation of IFTM, he will inform AOC and AOC will take the initiative to make a proposal. In the longer-term implementation, the process of co-ordination between ATC, AOC and Airport ATC takes place in the context of a multi-sector planner (MSP) implementation. This implies making use of 4D prediction and guidance capability of the aircraft. Also, aircraft/ATC/ AOC communication will make use of the capabilities to exchange planned trajectories.
• Optimisation of Arrivals (7.4)	Arrival Management functions produces Required Time of Arrival at the threshold (RTA) and at the metering fix (RTA_{MF}). Under CDM, Required Time at the metering fix (RTA_{MF}) is send to the pilot, who is responsible for meeting that time. Route changes provide the opportunity for larger variations in arrival time than can be achieved by speed control alone, but would need to be negotiated with any affected en-route ATC units. This leads on to an aspect of the in-flight Traffic Management application of CDM. Allowing AOC to influence the planned arrival sequence according to their own priorities, requesting swaps in the planned arrival sequence. AOC should be able to notice estimated delays, and to propose priority in releasing flights from the stacks.
• Autonomous Separation in FFAS (7.6)	This application has not been developed in detail by the project.

A.10 DADI

The DADI (Datalinking of Aircraft Derived Information) project consists in two parts. Part 1 of the project started in early 98 and finished in late 99. Consequently to this initial project, the commission decided to fund a continuation of the project (referred as “DADI-2”) which activities will expand until mid 2002. The two parts are therefore described separately (DADI-2 has just started and expected results can be of interest for AFAS/MA-AFAS projects).

A.10.1 Datalinking of Aircraft derived information (Part 1).

A.10.1.1 Objectives

The project’s principal objective was to explore, in various near-operational scenarios, the general concept of ‘DADI’ – the Datalinking of Aircraft Derived Information - in order to provide for the highest priority requirements of various types of ground-based users. Three complementary evaluation sites were thus set up to investigate the DADI concepts, to evaluate the implementation options and to assess the user benefits in various operational scenarios.

Evaluation sites were set up in France, Norway and the Netherlands. The Norwegian evaluation was concerned with the exploitation of ADS/ATN for improved control of helicopter operations over the North Sea, beyond the range of radar. The French evaluation site was based around the Sofréavia/STNA Mode S facilities at Toulouse, and made significant use of the DERA BAC 1-11 ‘flying laboratory’. The Netherlands real-time simulation platform was upgraded to qualify and quantify the benefits of aircraft data in surveillance and medium-term trajectory prediction in high air-traffic density airspace.

To supplement these practical evaluations, a further work package exploited the NLR ‘TOPAZ’ (Traffic Organisation and Perturbation AnalyZer) tool to assess analytically the capacity and safety benefits of the DADI concepts.

A.10.1.2 Method used

The DADI project contained eight work packages. WP1, dedicated to management, along with WP8 – Dissemination - were supporting activities for technical activities developed in WP2 to WP7.
The following figure provide an overview of the DADI work package flow.

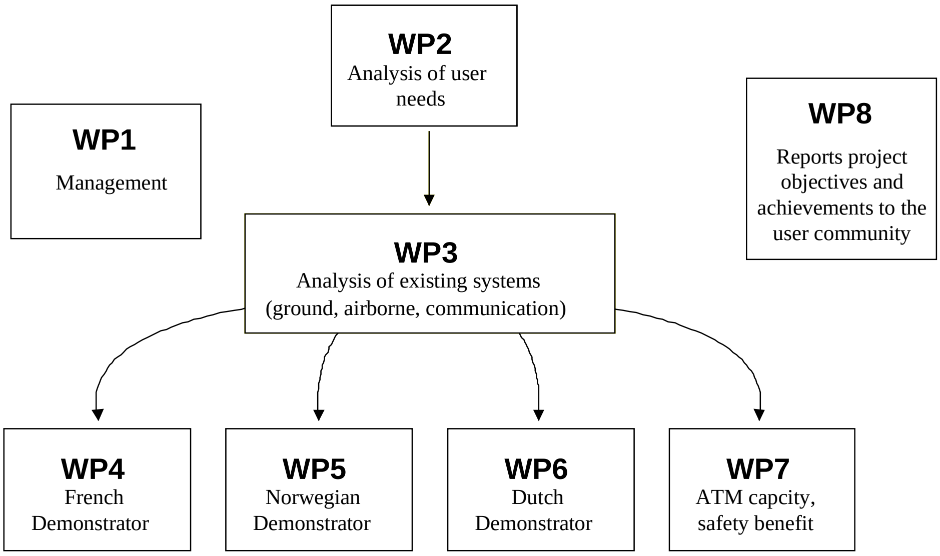


Figure 4 - DADI Work Package flow

WP2 and WP3 were common activities conducted to express state of the art requirements and technologies able to support datalink of aircraft derived information concepts.

The principal objectives of WP2 (“Confirmation of user requirements”) were three-fold:
To provide a general review of the existing literature concerning potential uses of aircraft data in a wide range of scenarios and timescales;
To provide guidance to subsequent DADI work packages on the specific uses of aircraft data within their chosen scenarios;

To make recommendations where appropriate to other European groups, based on the harmonisation of information obtained from work on Objective 1.

The objective of WP3 (“Synthesis of airborne and ground-based System architectures”) was to start from the information requirements of the ground applications identified in WP2, to analyse how the data might be communicated through the various contemporary air-ground data links, and to assess the potential sources of such data in modern aircraft.

WP4, WP5 and WP6 corresponded to the specification, development and demonstration of the DADI platforms which included:

Mode-S specific operations (Sofreavia/STNA/AATM/DERA, WP4)
ATN based operations (Kongsberg Defense Aerospace, WP5) in North Sea area.
Simulation activities (NLR, WP6) using NARSIM facility.
WP7 conducted an overall Safety Analysis on a dedicated scenario using Datalinking of Aircraft Parameter.

A.10.1.3 Main results

User requirements (WP2).

First, an overview was derived of the requirements for air-ground data exchange, both from the global (ICAO) and from the European (EATCHIP) perspectives. Then, a general review was performed of the ‘user requirements’ of ground-based applications for aircraft data, based on the

detailed analysis of over 100 documents. These documents, which encompassed the 'State of the Art' up to mid-1998, covered aspects such as standards, policy, strategy, operational concepts, formal requirements, benefit analysis and specific projects.
The analysis of documents was somewhat disappointing, since very few documents even attempted to provide the detailed specification of user requirements that was needed. Based on the most relevant information from the literature survey, detailed reviews were performed of the precise data requirements of selected applications. Inconsistencies between documents were then identified, and recommendations were made, particularly to the EUROCONTROL ODIAC group, for the harmonisation of these stated requirements. Outputs from WP2 can be found in *DADI D2.2 : Confirmation of User Requirements (v1, 25/3/99)*

Synthesis of airborne and ground-based System architectures (WP3)

The various platforms available to the DADI partners were reviewed against this background of requirements analysis and architecture options. In this way, assurance was obtained that the three DADI evaluation systems would be developed to be representative of realistic operational systems, and would be designed with regard to the requirements of the ground applications. Outputs from WP3 can be found in *DADI D3 : Synthesis of available European DADI-based platform (v1.A, 29/6/99)*

DADI Platform development and evaluation

Mode-S specific trials

- The ground-based evaluation site was centred on the STNA facilities at Toulouse in southern France. The main sub-systems comprised:
- The Experimental Mode S radar ground station, already fully developed;
- The "RSTNA" ground communications network;
- The Ground Data Link Server, built for DADI, to act as the co-ordinating interface between the Mode S system and the ground-based users of information;
- The Controller's display suite, enhanced for DADI;

The three types of contracts have been investigated: on demand, periodical, on event (dataflash). In all cases, characteristics of the management of the service and the delivery of the data were evaluated.

The airborne facilities were installed in the DERA BAC 1-11. The critical component installed for these trials was the Mode S Airborne Datalink Processor (ADLP), interfaced on the one side to the Mode S transponder and on the other side to the aircraft's standard ARINC 429 data buses. The ADLP, developed for EUROCONTROL by NLR, supported not only the update of the transponder's BDS registers, but also the 'Dataflash' service, both being defined in the ICAO 'Manual of Mode S Specific Services'.

During the 4 flight trials, some 40 'Periodic' contract requests were scheduled for various aircraft parameters, with reporting periods spanning the range from 8s to 256s. In addition, 94 'On Demand' requests were made, again for a wide range of aircraft parameters. Furthermore, 19 'On Event' (Dataflash) contracts were set up, exploring a wide range of event criteria. In all, over 2800 aircraft parameter reports were delivered in this period.

The aircraft parameters that were investigated, and the BDS registers from which the data was extracted, included Ground speed and Track Angle (BDS 5,0), IAS and Magnetic Heading (BDS 6,0), Wind Speed and Direction (BDS 4,4), Next Waypoint (BDS 5,4), Selected Altitude (BDS 4,0)

The evaluation scope was limited to the systems that DADI projects had developed (i.e. Data Link Server, HMIs). The evaluated systems showed good reliability and performance even if some limitations were imposed by external systems : Improvement can be expected with the design of the POEMS stations, which allows for shorter rotation periods (4s instead of 8s), more interrogations per aircraft, and the extraction of AICBs (dataflash) during a single aerial rotation.
DADI partners also provided EUROCONTROL with some useful feedback on the early airborne Dataflash application as it contained some few defects that could be corrected.

The various contracts that were set up allowed identification of whether requirements established by ODIAC could be met. The general conclusion is that the expressed requirements should differ according to phases of flight (especially for magnetic heading and AS for which the ODIAC requirements could not be met in approach phase).

ATN helicopter trials

The Norwegian demonstrator has evaluated the technology of downlinking aircraft derived information from helicopters in remote areas that are without other means of surveillance. Offshore helicopters, serving the oil installations in the North Sea and northern Norwegian waters experience such an operating environment.

One particularly notable feature of this evaluation is that operational ATCOs at three ATC Centres in Norway used the ADS displays, and the 9 fully equipped helicopters were engaged in routine offshore operations.

Air-ground communication was via an ATN-compliant network using the Inmarsat Data-3 service, employing the P-channel for up-link messages and both the R-channel (random access, short messages only) and T-channel (TDMA (Time Domain Multi-Access), longer messages) for down-link.

Between April and August 1999 many data collection trials took place, with nearly 100,000 downlinked reports recorded. Of these, some 36,000 reports were obtained in circumstances suitable for performance evaluations. The following analysis results relating to datalink performance were obtained:

Transfer time, short messages: in different trials, average values were between 4.6 and 9.1 seconds;
Transfer time, long messages: average values between 11.3 and 13.9 seconds;
Missing reports: 99.7% of scheduled reports correctly received, with all ‘missing’ reports accounted for;
Network congestion: only 13 occurrences due to high datalink loading over 161 days (usually due to saturation of the R-channel when the reporting interval was effectively 7.5s);
Satellite handover: 95% (of 91 events) were completed within 100 seconds.

The analysis relating to the ground applications has so far covered the following issues:

SSR / M-ADS position discrepancy: maximum difference 1.22 NM;
Air / ground status reports: a useful supplement to existing methods;
Applicability of M-ADS parameters to Flight Information Services: several parameters of value to the FIS ATCO;
Emergency alerts: downlink transfer time of first emergency report <11s (23 synthetic examples, all via the slower T-channel).

Simulation environment

The Evaluation Site in the Netherlands has enhanced and exploited the capabilities of the NLR ATC Research Simulator 'NARSIM' for qualifying and quantifying the benefits of DAP in high traffic density airspace representative of Central Europe. This Evaluation platform offers three principal capabilities that are complementary to those of the other DADI evaluation platforms:
Assessment of operational issues with realistic traffic flows, defined exceptional cases and selectable ATC procedures;
Flexibility, particularly regarding the set-up and execution of experiments;
Potential for systematically manipulated experiments, leading to statistically significant results.

One of the most significant developments was to the controller's HMI, where the addition of DAP data was expected to increase the ATCO's situational awareness while reducing the need for a certain amount of R/T use. The DAPs that were initially considered for display included IAS, Mach, Magnetic Heading, Vertical Rate, Wind Speed and Direction, and Selected Flight Level, Speed and Heading.

An enhanced Trajectory Predictor (TP) was designed to take Downlinked parameters into account. This increased significantly the accuracy of such a tool, which will be used in other applications (e.g. Arrival manager)

NARSIM is now ready for pre-operational validations of DAP-related activities in en-route and ACC environments. It is anticipated that the enhancements required to permit evaluations in fully operational environments could readily be accommodated.

Safety assessment

To achieve this type of assessment, the NLR 'TOPAZ' (Traffic Organisation and Perturbation AnalyZer) methodology, a model-based approach to risk assessment, was used to perform a dedicated ATM version of Probabilistic Safety Analysis (PSA). This approach is frequently used to analyse safety-critical situations in other industries.

Quantitative comparison was required between two operational concepts in the same traffic scenario. The 'baseline' concept represented a conventional ATM situation with no air-ground data transfer, while the 'advanced' concept included downlinked aircraft data used to enhance ATCO monitoring, supported by improved tracking and automatic Flight Path Monitoring (FPM). The PSA was applied first to the baseline scenario and then to the advanced scenario. The evaluations were then repeated for a range of separation standards.

The following main conclusions were drawn:

Supporting ATCO routine monitoring by the advanced FPM significantly reduces accident risk;
The increase in required controller effort due to the FPM alerts (including false alerts) is relatively small;
The occurrence of unexpected Sharp turn deviations caused by discrepancies between ATCO control plan and flight plan remains the primary contributor to accident risk.

A.10.1.4 Key Concepts and Requirements Identified

DADI-1 has explored the near term possibilities for DAP related systems mainly used in en-route environment, taking advantage of the three developed platforms. The technical feasibility has been proven which justifies the subsequent activities undertaken in DADI-2.
Deliverable D2.2 "Confirmation of user requirements" focuses on DAP but could be used in AFAS/MA-AFAS projects for the high level reviews which was made of the several documents (more than a hundred).

A.10.2 Datalinking of aircraft derived information (Part 2).

A.10.2.1 Objectives

The continuation of the project, DADI-2, will build upon the results of the DADI-1 project and will concentrate on the near and medium-term exploitation of aircraft data in ground Air Traffic Control systems.

A set of three DAP (Datalink Aircraft Parameter) tools will be addressed by the consortium:

Provision of aircraft parameters to the controller for core European en-route airspace, evaluated in the French pre-operational environment.
Development of an Enhanced Arrival Manager improving capability of automation support, evaluated in an ATC simulated environment.
Benefits of dual data links (including the impact on safety) providing aircraft parameters in off-shore, uncontrolled airspace, evaluated in an operational environment using Norwegian offshore helicopters.

The evaluation of these tools will take place within the Open Communication Architecture Concept. Each tool will take advantage of all communication means made available by the aircraft, transparently to the end-user, so as to offer a higher quality of service, efficiency and flexibility. Various communication means will be addressed (ATN, Mode-S Specific services, ACARS, VDL-4/STDMA) in terms of performance and safety, against the requirements identified for the operational concept associated with each tool.

An overall Business Justification will be prepared that will be based on the benefits to many users.

A.10.2.2 Method used

The Open Architecture Concept

A major objective of the DADI-2 project is to develop and evaluate an open communication infrastructure concept. Such an open architecture will provide airline operators a maximum flexibility to choose the desired air/ground network(s), whilst meeting the requirements to operate in a given airspace.

An Open Architecture has been defined by ICAO in the Aeronautical Telecommunication Network (ATN), through which several packet data air/ground sub-networks can co-exist.

Another level of Open Communication Architecture allows additional flexibility through the recognition of different air/ground (and air-air) communication networks.

In order to avoid upgrade of the systems whenever a new air/ground communication network is introduced, a ground-based data link server will be specified , which will have one common interface with the end user (i.e. ATC system) on one side, and supporting and managing message exchanges via different air/ground communication networks (ATN, ACARS, Mode S specific services, VDL-4/STDMA, etc.) at the other side. The data link server will be integrated within the French operational environment (CAUTRA) and will be evaluated with test flights (NLR Citation research Aircraft) as well as commercial flights (British Airways).

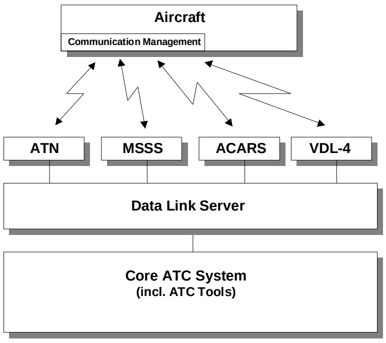


Figure 5 - Open Communication Architecture illustration

In addition to the way these communication means can coexist, the performance and safety aspects of each candidate air/ground networks need to be assessed, and compared against the operational needs. The System Assessment work package (WP2) will study the cohabitation of multiple air/ground networks, and the associated safety and performance aspects. This will be studied considering different typical European air spaces.

DAP Enhanced Tool

A number of functional applications have been identified which will have to be adapted to enable the possible benefits of ground usage of Aircraft Derived Information. These applications are:

- Tracking
- Controller Situational Awareness through new HMI Trajectory Prediction
- Short Term Conflict Alert (STCA)
- Medium Term Conflict Detection (MTCD)
- Inbound scheduling
- Minimum Safe Altitude Warning

The objective within DADI-2 is to specify, develop and implement one of these enhanced controller tool in order to enable the identified benefits of the initial use of aircraft data via Mode S enhanced surveillance, ATN or VDL-4/STDMA. Other projects have only addressed tracking, Human Machine Interface and Medium Term Conflict Detection. DADI-1 complemented this list with the design of DAP enhanced Trajectory Predictor.

In DADI-2, a DAP enhanced Inbound Scheduler will be developed that uses the Trajectory Predictor from DADI-1. The Inbound Scheduling tool will be designed flexible such that the performance will be improved through the availability of different types of aircraft data, ranging from currently defined parameters such as position information, state vector (e.g. air speed), short term intent information, to more advanced parameters such as aircraft weight, 4D way points and performance windows. Such a design will ensure a short-term implementation while enabling the tool to support transition periods to a more data-link capable environment.

Redundant Data Link for safety critical DAP applications

The DADI-1 evaluation of the DAP service ADS Contract in the environment of operational off-shore helicopter flights in the North Sea area demonstrated that this service via the ATN/AMSS air/ground datalink improved the ATC emergency alerting and Flight Information Service for en route flights in a non-radar airspace and increased safety. However, the DADI-1 evaluation did show that the AMSS data link has a message rate limitation of about one parameter set every 11 to 15 seconds, depending on the size of the parameter set. This means that the update rate of information at ATC displays is too low to support a proper FIS in the terminal areas of offshore installations or other remote landing sites. Furthermore, the current data link architecture does not provide sufficient performance to enable controlled airspace in parts of the Norwegian sector of the North Sea, which is the goal of oil and gas companies, the helicopter operators and the NCAA.

Experiences from the datalink evaluation in DADI-1 suggest that the existing AMSS datalink architecture should be supplemented by an additional air/ground data link technology (this way improving datalink throughput performance and safety). To facilitate such an upgrade, DADI-2 will define a datalink architecture and identify arguments and inputs to a performance and safety analysis for the identified architecture. This system specification and analysis information will be valuable for short and medium term implementation of DAP based Air Traffic Control.

The implementation of the evaluation system will be based on systems and equipment already available. One major candidate for supplementing the AMSS technology used for ADS-C in the off-shore helicopter environment is the VDL-technology which offers an ADS Broadcast as well as a two-way air/ground data link capability at the same time.

The implemented architecture will be evaluated by using offshore helicopters during revenue flights to assess the technical performance as well as the operational impacts. The results of this evaluation will be compared with the operational performance requirements for the airspace upgrade.

Business Justification

The assessment of the benefits will take advantage of past experience, as well as outputs from DADI-2 Work Packages. Capacity/efficiency benefits through open architecture concept benefits by reduction of ground costs and increased flexibility for airlines to choose their D/L system and assessment of the safety benefits of dual datalinks will constitute the basis for this Business Justification.

DADI-2 Evaluations performed at two ATC sites (in both the core area of Europe and on the fringe) and one ATC simulation facility using a complete set of upgraded controller assistance tools will provide a basis for this study. The composition of the DADI-2 consortium, consisting of CAAs, an airline, research organisations and industrial partners constitutes an asset for the project, ensuring that the correct inputs are introduced in the Business Justification, by the various actors of the ATM community.

A.10.2.3 Expected results

The expected achievement of the project is to pave the road for future deployment of ATM services in relation to Datalinking of Airborne Parameters (DAP) by:

- Defining how datalink technologies can work in parallel to enhance safety in the context of the DAP service.
- Establishing a coherent open architecture concept where the appropriate air/ground data links can be used transparently for the ATM applications or Air Traffic Controller. The ATM users will be delivered aircraft derived data (possibly from a combination of Air/Ground data links) at the necessary level of reliability and integrity.
- Quantifying improvements to controller’s tools by use of aircraft derived information and assessing impact on traffic capacity and flight safety.
- Preparing operational introduction of DAP for technology implementation plan with a justified business case.

A.10.2.4 Key Concepts and Requirements

Part 2 of the DADI project should bring DAP application to the stage where operational implementation is then a choice from Decision-Makers. Phasing of the project is very close from AFAS/ MA-AFAS projects and DADI-2 could bring valuable functionality (ground systems) to test against (NLR NARSIM and SOF/STNA pre-operational environment). End-to-end tests which are planned in both projects could take advantage of DAP facilities which are provided outside their scope (CAP, Arrival management functions, etc.)

A.11 EOLIA

A.11.1 Objectives

[1]
EOLIA (European pre-Operational datalink Applications) is a European Commission (EC) and Eurocontrol sponsored project which has the objective to develop and evaluate a set of user-oriented ATN compliant, pre-operational ATC data link services in the European environment to enable the improvement of Air Traffic Management (ATM) taking into account the interests of the users and the European Industry.

[4]
The EOLIA Project, started in January 1996, aims to demonstrate the benefits of datalink to airlines and other airspace users by evaluating air traffic control Datalink Services for future operational implementation in European airspace.

[2]
EOLIA is working in close cooperation with the ProATN project, which provides the underlying communications infrastructure for delivering messages to and from the aircraft.

A.11.2 Methods Used

[1]
For **demonstration** and evaluation of feasibility, the EOLIA data link service software has been installed at **four ground sites**, and initially in **ground-based aircraft simulators**. Later in the project, aircraft took part in **flight-testing**.

[4]
The **study** provides a framework for assessing the costs and benefits of specific datalink services of the type that could be expected to become operational by 2005.

[4]
The **User Forums** (involving pilots, airlines, controllers, CAAs, pilots and controllers associations…) provided guidance to the project by selecting the most promising data link services, then approving the final user specifications.

[4]
Verification of the EOLIA data link service software and its implementation is being undertaken in three parts. The first step involves ‘local’ verification of the air and ground systems independently. The next step is end-to-end testing between ground and airborne system. The final stage of verification covers the correct operation of the data link services from the user’s perspective.

A.11.3 Main Results

[4]
The EOLIA consortium has developed the software, which provides the datalink service functionality as 'Service Layer' code. The Service Layers both interface with the ProATN infrastructure thereby providing interoperability between the two sub systems. The Ground Service Layer, as a common component shared on each partner platform, will allow a fully interoperable multi-sited air/ground system. Each ground site partner is developing a bespoke Human Machine Interface (HMI) to provide the user with access to the functions of the datalink services.

[4]
The ground platforms (including the common "Ground Service Layer" and proprietary HMI modules) were all tested against airborne components.

The complete airborne software was developed by Aerospatiale Matra - Airbus, and integrated in the airborne equipment which will be used for FANS-A operations in 2000, the ATSU (Air Traffic Services Unit). The aircraft target was the A340. the HMI components were those used for FANS-A.

NLR integrated the A340 ATSU in their Cessna Citation, emulating all the interfaces between the ATSU and its environment.

[4]
NLR / Airsys ATM have demonstrated a complete Flight Plan Consistency check (FLIPCY) for the first time under real-life flying conditions. In total, five successful ProATN/EOLIA flight trials have been performed for the FLIPCY service evaluation.

[4]
NATS has conducted three datalink simulations as an integral part of the EOLIA operational evaluation activity.

ProATN/EOLIA were successfully demonstrated to a wide aeronautical audience during the Paris-Le Bourget Air Show in 1999. A controller station located in the Thomson CSF - Airsys ATM stand performed operational scenarios with the Aerospatiale Matra - Airbus A340 simulator and the NLR Cessna Citation, both of them equipped with the ATSU and Datalink HMIs. A video link was set up between the AM Airbus laboratory in Toulouse and the Airsys stand in Paris. During the demonstrations, the public was able:

- To track the two aircraft in the controller screen thanks to the information provided by the services built upon the ADS applications
- To watch at the CPDLC exchanges between the controller and the two controlled aircraft on the controller work station. In addition, it was possible to see in real time how the crew "flying" the A340 used the system.

A.11.4 Key Concepts Identified in EOLIA Project

[4]
The Datalink Services automate some of the routine voice communications between the controller and pilot.

[4]
The use of a datalink to take over some of the R/T workload could lead to significant increases in ATC capacity.

[4]
The use of an air/ground datalink as a supplement to radio-telephony (R/T) has the potential to provide a number of safety enhancements to ATC and its users.

[3]
The **User Forums** selected the following eight datalink services for research by EOLIA: **DLIC** (Datalink Initiation Capability), **ACL** (ATC Clearance), **ACM** (ATC Communications Management), **APR** (Aircraft Position Reporting via ADS), ***ATIS*** (Automatic Terminal

Information Service), **DSC** (Downstream Clearance), ***DYNAV*** (Dynamic Route Availability), **FLIPCY** (Flight Plan Consistency).

[4]
DYNAV and *ATIS* services have not been implemented by EOLIA.

Note: CIC is the new "official name" selected by ODIAC for the ACL service

[4]
Use of an Air/ground datalink will reduce the workloads of pilots and controllers by automating some of their routine operations and using R/T communications more efficiently. Analysis has shown that a reduction in workload of 9% could be achieved with 100% datalink equipage using the ACM and FLIPCY services in a scenario involving two boundary sectors.

[4]
HMI is a key element in successful use of data link in the ATM. Sofreavia ground system has identified the need for controller to access two aircraft parameters (heading, speed) in order to be able to simplify the controller input and uplink the appropriate message.

[4]
In order to issue a simple clearance (e.g. heading, flight level, speed,...) the controller only indicates a value, and the HMI processes that value in order to send the correct CPDLC message. For speed and heading clearances, this principle cannot be applied without the knowledge by the system of the current values. This restriction can be solved by presenting to the controller two downlinked aircraft parameters (DAPs): current speed and current heading.

NOTE: Concept of coupling particular datalink services to increase overall efficiency- in example the use of DAPs to optimise the controller's interaction with the system and therefore reduce controller's CPDLC workload.

A.11.5 Key Requirements Identified in EOLIA Project

[4]
EOLIA has adopted the operational requirements for ATC datalink services, outlined by the ODIAC task force, established by EUROCONTROL.

[2]
The services comply with the International Civil Aviation Organisation's (ICAO) standards, in particular those derived for CNS ATM-1 ATN SARPs.

NOTE: As EOLIA project uses the ProATN infrastructure, the EOLIA services are ATN-compatible.

A.11.6 References

1. http://www.eurocontrol.be/projects/eatchip/link2000/EOLIA.htm
2. http://www.trentel.org/transport/research/Projects/eolia.html
3. http://www.sdd.nats.co.uk/e/prj/0033/0033%2D1.htm
4. http://www.eolia.org/
5. EOLIA Initial Verification Report, EOL/WP6/SOF/057/62/P/1.0

A.12 FACTOR

A.12.1 Objectives

The primary scientific objective of the FACTOR programme has been to define assessment criteria and develop an assessment methodology for the assessment of functional concepts. This has culminated in the issuing of two-work package reports, one on the assessment criteria and the other on the assessment methodology, upon completion of the study. In addition, the overall FACTOR project final report, which provides material based on all the technical work undertaken during the course of the FACTOR project, has been issued.

The work has resulted in the completion of the comprehensive and representative set of functional concepts (work package 1) culminating in the issuing of the WP1 Final Report. For work package 2 formulation of selection criteria, defining of associated assessment questions and how these relate to the assessment methodology of WP3 has been completed. The approach has clear links with our original proposal through the AEGIS assessment criteria, has relevance to existing EATMS activities through relating assessment criteria to the Invariant Processes domains and also links well with user and operational requirements through the defining of criteria which relate to benefits that may result from the selection of particular functional concepts. The final report for WP2 was issued on completion of the project.

Further development of the assessment methodology was concluded and the associated WP3 Final Report issued to the Commission. The approach taken recognises the distinction that exists between the problem space on the one hand and the solution space on the other where these relate to the requirements and the functional concepts respectively. Using this simple model the assessment methodology resulting from work package 3 follows a step-wise screening process where concepts are selected and refined, rejected or retained for further revision at each stage of the assessment. The methodology is a five-stage process of mapping and classification, coarse and individual assessment, and inter-dependencies assessment, utilising the assessment criteria developed within work package 2. In parallel with the developments of the assessment methodology, work on the use of rankings and weightings to assist with the qualitative assessment of concepts has been progressed; however, this is no longer a substantial part of the methodology through taking account of the review feedback received at the workshop.

Recognising the need for close links between work packages 2 and 3 in order to have a satisfactory conclusion to the project, the framework document produced during the first 6 months of the project has been maintained and updated to reflect current thinking on both WPs 2 and 3. This document states clearly how the two work packages satisfy project objectives, have clear links with work package 1 and are compatible and complementary to each other. The overall framework builds on the assessment methodology model of there being both a solution space and a problem space and shows how the approach to defining selection criteria within the Invariant Processes domains and relating them to benefits is compatible with the assessment model. Further elaboration of the step-wise screening process is provided and the value of producing a "golden set" of functional concepts, utilising the work of work package 1, against which we can exercise our assessment methodology and refine our assessment criteria is described.

The FACTOR final report is essentially the framework document described above with additional material relating to the work of WP1 along with summary and introductory sections appropriate to such a document, thereby ensuring it is a standalone document which reflects fully the technical work of FACTOR. This report was issued on completion of the project.

A.12.2 Methods used

The purpose of the FACTOR project was to develop a methodology for the assessment of functional concepts in the context of the user and operational requirements that exist for the ATM industry in Europe.

The FACTOR methodology developed provides a flexible means for the evaluation of functional concepts (FCs), with elements of top-down and bottom-up assessment. Bottom-up assessment works by choosing the low level elements of the system and integrating these to form a more complete picture of the ATM system, identifying at each stage the candidate concepts which satisfy these low level elements, this is reflected by the manner in which FCs form the base of the methodology. The top-down approach reflects the fact that assessment may commence with a cluster of concepts, which are selected to satisfy an ATM scenario. In this case a model of the ATM system is chosen against which the selected concepts can be assessed to ascertain completeness of the ATM scenario. For this methodology the Invariant Process model of the ATM system has been chosen; this is a model based on the processes that must occur within the system for it to function and also one developed by the ECTF.

The FACTOR programme built on previous work, such as AEGIS and ATLAS, and on current ongoing work such as EATMS which produced the EO-DP document for functional concepts. FACTOR has attempted at all stages to complement and to build on current thinking within the ECTF through, for example, the presentation of interim results and the running of a workshop.

The aims of the FACTOR programme were to:

- Produce a comprehensive set of functional concepts;
- Define assessment criteria;
- Develop an assessment methodology;
- Ensure the ATM community are aware of the work and results; and
- Produce work of relevance to the ECTF.

These objectives are reflected strongly in the breakdown of the technical work. The FACTOR programme consists of three technical work packages:

- WP1 "Extraction and categorisation of the set of Functional Concepts";
- WP2 "Define assessment criteria"; and
- WP3 "Develop an assessment methodology".

The first work package forms the basis for the development of the assessment methodology, as it provides the set of functional concepts that currently exist for ATM. The second two packages complement each other in that WP2 derives the criteria upon which the methodology is based, and WP3 provides the methodology itself. Both were progressed in parallel and the results of each helped direct and shape the work of the other.

A.12.3 Main results

This section explains in outline the technical work carried out during the course of the project and gives an outline of the FACTOR methodology and its 5-stage structure. The results of the work are framed around the three technical work packages of the FACTOR project, as described in the previous section.

WP1 is concerned with the analysis, collation and the categorisation of the functional concepts originating from various system philosophies, which act as a reservoir of ideas for use by the assessment methodology. The working definition of an FC within FACTOR is defined as "... a specific idea to incorporate a particular operational function into an ATM system...". In this definition, a FC deals with the abstract "what" question, whereas operational/technical concepts cover the "how" of implementation. The set of FCs outlined in WP1 was drawn from a number of sources, mainly the EATMS Options Discussion Paper (EODP). The set is comprehensive but not exhaustive, can easily be added to and is expected to be extended during the use of FACTOR (even if only through concept clarification). Within the WP1 report, the FCs are organised according to the divisions that were adopted for the EATMS options, ensuring transparency with existing EATMS work and ease of reference for the later work packages.

WP2 shows how the assessment criteria to be used were derived from the EATMS user requirements, along with giving details of each of the criteria within the IP structure and providing further notes on the methodology given in detail in WP3. The work was initially based on previous work such as AEGIS and ATLAS, and then drew upon the user requirements in order to prepare a list of criteria that is as complete as possible. The criteria themselves are high level concepts, such as capacity, against which the FCs are compared to see if there is likely to be any improvement or degradation of ATM service against the baseline indicated in the assessment by the assessor. As the user requirements were used to derive the criteria, there is a direct trace from the criteria back to the URs, an important aspect to consider when trying to optimise UR coverage of a concept. The criteria are used within the methodology structure outlined in WP3.

As noted above, the final work package, WP3 provides the outline of the methodology, how the FCs are assessed and how the clusters are built to form a scenario for a future ATM system. This method bases itself around the invariant process model, for which it describes in detail a suggested structure. As the methodology depends quite heavily on the IP structure, it will only be as complete as the IP model once finalised (which is continuing work being carried out by the ECTF). The methodology itself is broken into five stages, two for the categorisation and clarification of concepts and three for assessment and concept cluster building. This structure can be used in a non-linear way and has been adopted in order to make the methodology as flexible as possible. It is expected that assessors will come to use the methodology at many different stages of ATM scenario development, and FACTOR supports this through the mix of top-down and bottom-up elements within the methodology.

The five stages of the FACTOR Methodology

The FACTOR methodology is based on a 5 stage iterative process, which can be entered at any point depending upon the requirements of the assessment to be undertaken. The first two stages, A and B, provide the mapping of concepts onto user requirements and the invariant process model respectively. These mappings enable checks to be made during later stages to ensure completeness of the solution defined by the concepts selected, both in terms of satisfying the user and defining an ATM system. They also perform concept clarification, providing uniformity of description and removal of ambiguity, thereby reducing subjectivity when applying the later stages of the methodology.

Stages C, D and E are where evaluation of the concepts takes place, initially within stage C at a very coarse level to rank the concepts for further assessment and scope the work for the detailed assessment of stage D. The detailed assessment of stage D also divides into a number of steps, again to scope the work to a manageable size. Step 1 determines the number of criteria, with supporting aspects, relevant for the assessment; step 2 carries out the assessment on a concept by concept basis across all relevant invariant processes, producing crude scores as guidance for the assessor; and step 3 consolidates the results of the assessment based on which the assessor can decide whether a concept adds positive value to the ATM scenario. Finally, stage E addresses issues of completeness and complements for the group of concepts which comprise the ATM scenario and, based on the results, guides the assessor to further assessment work within the other stages.

Two tasks complementary to FACTOR were also carried out in parallel under another project, FACTOR/CT, funded by Eurocontrol. These were the entry of a subset of the FCs into a database and the definition of the relationships between the FCs and the URs. This work was necessary to provide links between previous ECTF work and the work of the FACTOR consortium, as well as providing a testing ground for the methodology. The final report for FACTOR/CT contains material which is directly relevant to FACTOR and should be consulted if further information is required regarding the categorisation of the FCs and URs, and how they relate to one another. Where appropriate, this material is drawn on within this report.

A.12.4 Exploitation

This project was fully funded under Contract AI-95-AM.102 for the EUROPEAN COMMISSION, Directorate for Transport DG VII and addresses Task 2 of Functional Architecture Requirements Analysis for ATM Concepts in the ATM Domain of the Transport Research Programme.

The main route for exploitation by the partners of the results of this work are through their continued links with EATMS activities on the part of Eurocontrol and through contributions to these activities by member states. The most likely form any exploitation of the FACTOR methodology will take is via Eurocontrol since this methodology provides a means for determining the ability of a grouping of functional concepts to satisfy system requirements on the one hand (the solution space) and user and operational requirements on the other (the problem space). This may prove very valuable in the future when the thinking for the OCD has been progressed.

Dissemination of the results of FACTOR has already taken place. The end of project presentation afforded an ideal opportunity to present our work and final reports have been circulated to all attendees. In addition, the close co-operation between the partners and Eurocontrol, including members of the ECTF, has meant that copies of the FACTOR reports have been distributed to a lot of interested parties inside Eurocontrol and those who regularly work with Eurocontrol staff.

A.13 FARAWAY

A.13.1 Objectives

The 4th Framework project "Fusion of Radar and ADS data through two-way data link (FARAWAY)" has been tasked by the Directorate General DGXIII of the European Commission under Contract-No. TR1025. The FARAWAY project is co-ordinated by Alenia Marconi Systems of Italy and has a large European project team. The project started in January 1996 and finished its first phase in July 1998. An extension of the program is currently still running until the end of this year under the name FARAWAY II (Contract-No. TR4012).

The FARAWAY project aims at the development of an appropriately equipped demonstration site to be used for pre-operational evaluation purposes (trials) to support new operational procedures based on the fusion of radar and ADS data through two-way data link (TWDL).

This novel technique, especially suitable for ATS message exchange including ADS information, allows "*enhancements in terms of operational performance of ground surveillance systems and aircraft navigation*" and improves Situation Awareness to the pilot through the use of "*on board frequently updated information on surrounding traffic"*. The CNS/ATM concept provides guidelines to manage increasing traffic demand through new technologies and automated tools. The technical solution envisaged by ICAO is based on the enhancements of both *Communication*, *Navigation* and *Surveillance*. The implementation of the ADS/B concept, together with a data link and accurate aircraft navigation system, shall result in an increased airspace flexibility and capacity and will improve traffic safety. The combined availability of a reliable data link together with ADS information broadcast to all airspace users could improve pilot Situation Awareness through the implementation of the Cockpit Display Traffic Information (CDTI) and Traffic Information Service (TIS-B) systems. Furthermore, the availability of accurate position information on a real time basis, both on en-route and on terminal operational domain will provide the users the possibility for gradually reducing the need of ground based navigation aids (VOR, DME etc.). It has been verified that the introduction of ADS/TWDL technique will provide improved Separation Standards in airspace without radar coverage and better surveillance standards in parts covered by Primary Surveillance Radar (PSR) and Secondary Surveillance Radar (SSR).

The objective of FARAWAY is to dedicate substantial effort to the development of a demonstration site equipped with innovative data fusion processors and data links, with purposely developed avionics ADS/TWDLs carried by a fleet of Airline carriers. Within this framework, most of the effort has been dedicated to the functional analyses and specifications related Data Fusion, ADS processing, data link communication services, on board automation mainly related to data acquisition from avionics equipment as well as avionics and pilot human-machine interfaces (HMI). The FARAWAY project has investigated 5 applications of the data link:

- **ADS-B:** ADS-B is a surveillance application in which aircraft transmit navigation data and other parameters to other aircraft and ground systems. The aircraft and ground systems in range of the transmission are able to receive and process the data for presentation on a display to the local users.
- **Enhanced Navigation:** Enhanced navigation in FARAWAY refers to the use of augmented GPS to improve the accuracy and integrity of navigation data on the aircraft (compared to not augmented GPS data). Improving the navigation data allows for more accurate aircraft navigation and also improves the quality of surveillance data reported via ADS-B.
- **Data Fusion of Surveillance Information:** Data fusion is the merging of surveillance data from different sources. In FARAWAY, these sources are the radar (PSR/SSR) and ADS-B systems. The fused data has higher accuracy, integrity and availability than either source on its own. It also results in more reliable data for conflict detection and conformance monitoring

function thus reducing the probability of false alarms; this is due to the availability of aircraft intent and kinematics data measured on-board and delivered by the ADS-B system.

- **TIS-B:** TIS-B is an application whereby traffic data is broadcast from a ground station to mobile users, so that it can be presented on the CDTI. The traffic data is obtained from PSR or SSR and may be fused with other data sources before being broadcast. The application allows users that are equipped with VDL Mode 4 ADS-B to have situation awareness of users that are not equipped. TIS-B thereby offers a straight forward transition solution
- **Airborne Situation Awareness:** Airborne situation awareness refers to the presentation of an air traffic picture to the cockpit crew. This gives them visibility of the positions and identity of all aircraft in the vicinity and means that ground controllers and pilots have access to the same surveillance information.

The FARAWAY demonstrator is now undergoing major enhancements in the FARAWAY II project to extend the VDL coverage to the Alps and to the Southeast Mediterranean and to add new capabilities. The main theme is that of transporting ATM services onto the VDL Mode 4 infrastructure and to proceed with FARAWAY with enhancement of scope so as to:

- Extend the coverage of the ICAO VDL VHF Mode 4/STDMA two-way datalink into the NEAN airspace and down to that of Brindisi.
- provide co-ordination with selected ADS trials conducted under National or European Projects, such as the Eurocontrol ADS Mediterranean Trials, PETAL II, NEAN/NEAP, SUPRA, Regional ADS projects by ENAV and other supported by the European Commission;
- secure Interoperability of FARAWAY and NEAN systems and Flight Management Services through the constitution of a pre-operational scenario adopting compatible technologies, providing inputs to on-going standardisation within ICAO, ETSI and EUROCAE and certification initiatives;
- perform a Feasibility Study for in-service adoption of an industrialised FARAWAY ADS-B system in selected airspace;
- Develop a set of advanced Validation Tools as part of a certification as safe for use process of the different technological domains covered by the trials.

A.13.2 Methods Used

FARAWAY is an ADS-B demonstrator set up at the Rome/Ciampino Area Control Centre (ACC) and onboard three MD 80s of Alitalia. It uses prototype VDL Mode 4 data link equipment to provide an ADS-B service, on top of which ATM applications are developed and evaluated. The main applications have been the data fusion of radar surveillance data (provided from a multi-radar tracker) with ADS-B reports, airborne situation awareness through onboard display and GNSS augmentation provided by prototype VDL Mode 4 ground station.

In the FARAWAY project, a complete data communications system has been established between a ground control centre and the cockpits of the Alitalia aircraft. The data communications system supports the ADS-B application and also the general transfer of data for other applications. The presentation to aircrew is through an advanced cockpit display unit that supports flight planning and other functions. The presentation to controllers is through a specialised air traffic controller workstation.

The FARAWAY demonstrator integrates into the existing Area Control Centre of Rome through the ASTERIX protocol and the Local Area Network. Flight trials were conducted with all equipment deployed at the test site and avionics integrated in the aircraft. Personnel off-duty and observers from the Consortium were active during the trials, checking surveillance, communication and data processing aspects on ground against the communication and navigation aspects as lived on board by the aircrew.

During the trials, all the relevant data were gathered from system(s) considered as “reference” and from the system developed within the project, both operating in the “real life environment”. An analysis on recorded data was then performed exploiting a number of software tools developed “ad hoc” or acquired. The overall definition of success was measured in terms of statistically meaningful evidence that the applications performed equal or better than the reference.

For technical assessment, the methodology was founded on the establishment, for each application to evaluate, of a set of correlated indicators, which are commonly accepted to describe the performances of the application. Meaningful statistical evaluation of the indicators was done to obtain a quantitative measurement of performances against the reference case. For user acceptance assessment, interviews and questionnaires were used to assess if foreseen benefits such as reduced workload, reduced communication, improved quality of information, HMI friendliness etc. have been achieved.

A.13.3 Main Results

The main project result is a pre-operational real time system exploiting real life data and operated by controllers and pilots in shadow mode. The FARAWAY demonstrator was validated with a number of “high level objectives” to be demonstrated:

- ADS Broadcast (ADS-B) using VDL Mode 4
- ADS-B and SSR tracking and data fusion
- Enhanced aircraft navigation based on GPS augmentation
- Traffic Information Service Broadcast (TIS-B)
- Airborne situation awareness on CDTI

During the trials, all the relevant data were gathered from system(s) considered as “reference” and from the system developed within the project, both operating in the “real life environment”, in order to:

- assess the **technical aspects**, verifying that the system works correctly from a *functional* point of view and measuring its *performances* through a set of correlated statistical indicators;
- assess the **user acceptance**, estimating the user’s attitude to the applications which exploit these new technologies utilised in the system, through interviews, informal task analysis, questionnaires, user workshops and other related techniques.

A considerable volume of data has been recorded for post-flight analysis exploiting more that 2000 flights, all routed North, South and West of Rome. The flight data has revealed flight profiles forming interesting patterns and has allowed analysis of the range of the data link to be undertaken.

The ADS-B data post-processing showed the prototype data link equipment to have a range of about 200 nm at most, with good properties of reliability and continuity up to the borders of the covered area (on the average, more than 98% of reports were correctly delivered, and this percentage always overcame the 95%) even if without using error correction techniques.

The effectiveness of the pseudo-range correction technique to improve in a local area the performances of the GPS navigation system was demonstrated as well. In fact, comparing the accuracy of the Standard Positioning Service given by the DOD (100 m and 150 m 95% errors respectively in the horizontal and in the vertical plane), with the one measured through the FARAWAY demonstrator a reduction of the error close to two order of magnitude can be observed. The data gathered also highlighted the vulnerability of GPS, since reduced GPS performance was found as aircraft passed over some military installations. This was due to interference from the installations that resulted in the decrease of GPS accuracy and the deterministic non-availability of the GPS signal in some areas. The capability of a GPS receiver to reject interference is implementation-specific and susceptibility to this interference varies between different GPS receivers and antennas. For the FARAWAY project no special equipment that could provide counter measures were used.

The data fusion demonstrated that better operational standards could be achieved by an integrated ADS/B-SSR surveillance system. The performances of the ADS/B reporting system guaranteed a continuous acquisition of the aircraft call sign, positional and attitude data so as to improve the process of report-track correlation, track filtering and prediction occurring in the ADS/B tracking algorithm. This results in an ADS/B track with a high level of accuracy even during aircraft manoeuvres.

The avionics display and situational awareness was shown to provide new benefits to aircraft crew. Before requesting a clearance, pilots were able to check if they were likely to receive it (by looking at the distribution of surrounding traffic). If there were many aircraft in the cleared area, the pilot would realise that the request would probably not be accepted. The pilot would therefore not make the request, thus saving workload for both pilot and controller.

Finally, FARAWAY aims to achieve progress through co-operation between industry, users and service providers. The results of FARAWAY include the feedback of all the user groups involved and this feedback has shown a positive view of the FARAWAY system. As users become familiar with the system, personnel become increasingly confident of its innovative features. In this way, FARAWAY has generated positive publicity amongst the user community, which encourages the adoption of advanced CNS/ATM technology.

A.13.4 Key Concepts and Requirements Identified

The results of FARAWAY will build an important basis for the development work in MA-AFAS. This holds true for the ground network as well as for the avionics package development. Since most of the FARAWAY partners are now actively involved in MA-AFAS a continuous information transfer and a suitable handling of IPR issues can be assured.

With regard to the future CNS/ATM technology the following key concepts have been validated:

- Automatic Dependent Surveillance Broadcast (ADS-B)
- Traffic Information Service Broadcast (TIS-B)
- ADS-B and SSR tracking and data fusion
- Enhanced aircraft navigation based on GPS augmentation
- Airborne communication functions allowing the transfer of various messages (ADS-B, CPDLC) via a VDL Mode 4 data link from the aircraft to and from the ground
- Airborne HMI that allows the handling of communication messages in correlation with flight planning interactions (i.e. presentation of communication messages on the CDU and the EFIS)
- Airborne HMI that realises a CDTI

The following key requirements for the onboard avionics have been worked out and realised in FARAWAY:

- the onboard avionics shall support VDL Mode 4 compliant data link communications
- the onboard avionics shall be able to receive, present and process CPDLC messages from ATC
- the onboard avionics shall enable the crew to generate CPDLC messages to be downlinked to ATC
- the onboard avionics shall incorporate an ADS-B function
- the onboard HMI shall incorporate the presentation and generation of communication messages on the EFIS and the CDU
- the onboard HMI shall incorporate a Cockpit Display of Traffic Information (CDTI)
- the onboard HMI shall incorporate information received via data link into the overall situation representation (for example graphical presentation of the updated trajectory)

The available specification documents as well as the validation results are expected to significantly influence the avionics package design of MA-AFAS.

Regarding the ground related functions it should be noted that the FARAWAY ground infrastructure is expected to be used in MA-AFAS.

A.14 FREER FLIGHT

A.14.1 Objectives

The objectives of FREER Flight are divided over two time frames. The first time frame addressed in FREER is the ATM environment in 2005 and beyond in which limited delegation of separation assurance to the cockpit is worked out. The second time frame addressed is 2015 and beyond in which full delegation of separation assurance to the cockpit is worked out. Both are described here since MA-AFAS concerns the ATM environment of 2005 and beyond.

The main objective for the near term part of FREER is to define a concept which allows for an increase of airspace capacity by mainly decreasing the controller workload. Which is established by a limited delegation of the separation assurance, on a case to case basis to the cockpit. The stepwise approach by starting with limited delegation towards more advanced full delegation is intended to allow for an evolutionary introduction rather than a revolutionary introduction of a new ATM concept. This evolutionary approach is expected to gain confidence from both pilots and controllers more easily than expected in a revolutionary approach.

In general FREER defines three stages of a traffic conflict: the problem identification phase (conflict detection), the solution identification phase (conflict resolution determination) and the solution implementation phase (conflict resolution activation). Within the near term concept, the ATC controller is at least responsible for the first step and the pilot at least for the third step. The responsibility of the second step depends on the level of equipage and ATCo decisions. In the longer-term concept the responsibility of all three steps are the responsibility of the cockpit.

A.14.2 Methods used

A.14.2.1 Methods used for near term

<u>The flexible, limited and extended delegation modes.</u>
The near term method comprises limited delegation of separation assurance. This means that the ATC controller is responsible for detecting the problem situation and optionally determines a solution for it. The pilot is subsequently responsible for implementing the solution and monitoring the problem being resolved. Within this near term concept two levels of delegation are used which directly influence the required cockpit functionality. These two levels of delegation are closely related to the three stages of a traffic conflict and resolution.

- In the limited level of delegation, the controller is in charge of both the problem and solution identification. Only the implementation of solutions and monitoring are delegated to the pilot.
- The extended delegation level, the controller is in charge of the problem identification and the pilot is in charge of the identification, implementation and monitoring of the solution.

The third level of delegation is a next level of delegation and represents the longer-term method, described in the next section.

A.14.2.2 Methods used for longer term

<u>The Autonomous Airborne Mode</u>
An aircraft operating in autonomous mode is fully responsible for assuring separation with other aircraft, restricted areas, weather and ground. It is assumed to be equipped with:

- ADS-B which enables it to exchange flight position information and trajectory intents with other aircraft
- an FMS which predicts the trajectory and guides the aircraft accordingly
- a system capable of detecting and displaying conflict areas.

Any trajectory change requires the new intent to be broadcast.

Own 4-D navigation information received from other aircraft is used to predict the minimum separation that will occur between own and any other aircraft. Whenever the predicted separation becomes less than the defined minimum, a conflict zone is displayed.

Traffic situations are assessed within the range of the ADS-B data-link. Presentation of loss of separation is restricted to those occurring within a useful time range according to a look-ahead parameter. Hence, any loss of separation occurring beyond this look-ahead range is ignored.

In case of a loss of separation between two aircraft, one aircraft has to keep flying on its current trajectory while the other aircraft has to manoeuvre. A priority assignment based on data exchanged through the ADS-B determines which aircraft has to manoeuvre. In order to define which of the two conflicting aircraft needs to take action, priority rules apply, referred to as extended flight rules or electronic flight rules. The first version of this set of priority rules involve only the conflicting aircraft while a second version of the flight rules is currently in preparation. This new set of rules do not only apply to the conflicting aircraft pair but also take into account surrounding traffic which is not (yet) conflicting.

Resolution to avoid loss of separation and no-go zones corresponding to minimum acceptable separation from the non-manoeuvring aircraft is performed similarly in avoiding thunderstorm areas. New waypoints to define the avoidance manoeuvre can either be provided by the resolution system or be entered manually by the pilot.

A.14.3 Main results

Both the near term and the longer-term concept have been evaluated in a number of man-in-the-loop evaluations including aircraft simulators and ATC simulators. Regarding the near term concept, qualitative results were obtained by using questionnaires and comments from both pilots and controllers. The result for the near term concept were summarised as “promising” and “having great potential”. This should be seen in the framework of the project in which was stated that an increase of airspace capacity would be achieved by reducing the workload of the controllers. The questionnaires and comments from the controllers indicate that delegating responsibilities to the cockpit reduces in most cases the controller’s workload indeed. However, the pilots indicate that in cases of delegated responsibilities the workload in cockpit is increasing rather than decreasing or remaining the same.

Regarding the longer-term concept also a number evaluations have been conducted. The results point out that pilots are positive about the concept but also concerns are expressed in the conclusion that the validity in higher traffic density airspace is questionable. Another concern is that CDTI leads to a visual overload to the pilots. However the overall conclusion is that the concept in itself is promising and having potential although not fully worked out yet.

A.14.4 Key concepts and requirements identified

The key concept used in MA-AFAS is based on an ATM environment with three types of airspace:

- Free Flight Airspace (FFAS)
- Managed Airspace (MAS)
- Special Use Airspace (SUA)

Basically three levels of delegation exist, the advanced level concerns full ASAS in FFAS aiming at a longer term (2015) while the other two levels of delegation are less advanced. Due to that it concerns MAS and allows for a sooner introduction (2005). The near term and longer term are however not different in approach but are intended to gradually evolve from one to the other depending on the equipage level of aircraft.

Requirements of the concept, in terms of on-board technology, are to have ADS-B (and TIS-B) for traffic information. In the advanced concept an air-air data link is required for priority determination. The use of the traffic information on board ranges from displaying it on the CDTI until full conflict detection and resolution algorithm depending on the level of delegation.

<u>Operational procedure in MAS</u>
In MAS the controller is responsible for separation. However on a case to case situation the ATCo can delegate a part of the responsibility to a crew for maintaining separation with respect on single aircraft. This delegation always ends after a limited period, which finishes after the crew indicates a ‘clear of traffic’.

<u>Operational procedure in FFAS</u>
In FFAS the crew is responsible for separation using on board conflict detection algorithms, a priority determination process and a conflict resolution algorithm in case the intruder aircraft has priority.

A.15 ISAWARE

A.15.1 Objectives

The main objective of ISAWARE is to improve flight safety by providing the pilot with a complete predictive situation awareness during all phases of the flight. Situational awareness is the state of the pilot being fully conscious of his surroundings. Integrated Situational Awareness System, ISAS, is one key concept that could regroup a number of services aimed at providing flight crews with perception of their operational environment. This knowledge comprises several fields:

- Terrain awareness: Ground Proximity Warning System (GPWS), Ground Collision Avoidance System (GCAS), Enhanced Vision System (EVS)...
- Traffic awareness: Airborne Collision Avoidance System (ACAS), Traffic alert and Collision Avoidance System (TCAS), Automatic Dependent Surveillance-Broadcast (ADS-B), Cockpit Display of Traffic Information (CDTI)...
- Weather awareness: meteorological radar, wind shear detector, wake vortex detector...
- ATM awareness: ATC broadcast, radar/weather situations uplink...

ISAWARE focuses on two major research axis:

✓ One is the outputs processing of the different safety items :
  - ACAS/TCAS,
  - GCAS/GPWS,
  - Weather radar,
  - Wind shear and wake vortex detector,
  - Terrain and obstacles detector,

  Taking into account other relevant information such as:
  - Flight plan,
  - ADS-B and up-linked messages.

  Increasing situation awareness will benefit from:
  - Prioritisation of alerts according to their risk level,
  - Filtering of alerts which are contradictory by deciding which alert is the most appropriate and what is the most relevant manoeuvre.

✓ The other axis of research is the development of a synthetic display to enhance Human Machine Interface. Since ISAWARE aims at enhancing the situational awareness during en-route, approach, final approach, climb and initial climb phases of flight as well as during final approach, landing, taxiing and take-off, head-down displays like EFIS (Electronic Flight Instrument System) or ND (Navigation Display) and head-up displays will be considered.

One main industrial objective is to specify, develop and manufacture items put together in the ISAS concept. Market analyses have concluded that the functions performed today by distinct units will be merged in the near future, thus meeting the modular avionics requirements. If the research is supported, ISAS concept could lead to the introduction of new products on the market around year 2005. We should note that this date has been targeted by American avionics manufacturers to market new products performing similar concepts.

A.15.2 Work Content

The project life cycle includes the typical phases required for comprehensive command of the project: requirements definition, system specification, development of a demonstrator, validation and assessment and, at the end, the exploitation/dissemination phase.
Hence, the project is split into six main work-package categories:

- ✓ WP1 is dedicated to collect, synthesise and validate users and operational requirements. Certification and safety constraints are also be taken into account in this WP.
- ✓ Based on these requirements, WP2 defines the conceptual and technical specifications of the ISAS system.
- ✓ A demonstrator is defined and developed during WP3. It is developed around a moving base flight simulator whose cockpit is representative for the current environment the pilot has to work in.
- ✓ Based on the flight simulator infrastructure, an evaluation environment is being defined and developed during WP4. Evaluation procedure and scenarios will be defined at this time.
- ✓ WP5 are dedicated to the evaluation of the developed concept with pilots from the different airlines involved in the project.
- ✓ An exploitation plan will be achieved in WP6.

The whole project focuses on civil fixed wing Air Transport application, from the requirements to the concept assessment. Nevertheless, Helicopter requirements were assessed in WP1 concluding with, during WP2, a report where the system differences between both applications were emphasised. Further phases on the project are concentrated on the Air Transport market.

A.16 M-ADS Helicopter Operations

A.16.1 Objectives

[6]
The purpose of M-ADS system is to improve safety by improved ATS with surveillance of all offshore helicopter operations on the Norwegian Shelf.

[9]
ADS- and radar-based Flight Information Service and Alerting Service will be provided inside the ADS areas to aircraft equipped with M-ADS. Air Traffic Service will monitor aircraft equipped with M-ADS the entire duration of the flight. This will provide the opportunity for direct routing of flights between land base and offshore destinations (and the other way).

[8]
One of the goals of M-ADS was that it should be an international interoperable system.

[6]
Future project objectives include VHF datalink for ATC Service, combined ADS-C and ADS-B (with CDTI and CPDLC).

NOTE: The project in the future apparently aims to provide improvements in the situational awareness for the helicopter pilots (CDTI/ ADS-B) and to remove the routine controller-pilot exchanges from the R/T channel to the data link (CPDLC).

A.16.2 Methods Used

[8]
During 1992 and 1993 Kongsberg **evaluated** several data link concepts.

[6]
In the first project phase the **communication-chain** of dataflow via datalink has been **tested**. In 1996 **operational testing** started with 2 M-ADS equipped helicopters. Since 1999 January 1st NCAA has made M-ADS **mandatory** for all helicopters operating on the Norwegian Shelf. Currently M-ADS (installed in 38 helicopters) is **operational** at Stavanger, Trondheim and Bodo ATCC.

[8]
During the Farnborough International' 96 exhibition, two M-ADS equipped helicopters provided the majority of ADS reporting for the demo. Similar **demonstrations** of M-ADS were also made at the 1998 Exhibition and Conference in Maastricht and at the 1998 ICAO Conference in Rio de Janeiro.

A.16.3 Main Results

[8]
Interoperability testing was carried out between the M-ADS airborne equipment and several ADS ground systems (NATS, CENA, NCAA).

NOTE: During the tests it proved necessary to enable the (normally typically disabled-) X.25 Fast Select facility across international gateways between national X.25 networks. The X.25 Priority facility could not have been used, as the ground router X.25 implementation did not support it. The M-ADS TSAP selectors had to be changed from initially one to two octets for interoperability reasons. Different ground routers used for interoperability tests showed different degree of conformance to the ICAO SARPs. Different settings of communication protocol timers did not affect the interoperability.

[6]
M-ADS resulted in **improved alerting service** by providing automatic alarms (blinking, colour, sound, position, time) when either the update of radar-track has failed, update of an ADS-track has failed, an abnormal descend occurred or the pilot initiated emergency signals (including three dedicated SSR codes)

[6]
M-ADS also offers the basis for the **improved flight information service** due to the ability to request ADS data and present integrated ADS- and radar tracks to the controller at the same display. The ADS application provides exact traffic information, collects (via ADS) information from helicopter FMS, maintains continuous surveillance (direct routing), avoids voice position reports (reduced R/T channel load, improved controller alertness).

A.16.4 Key Concepts Identified in M-ADS Helicopter Operations Project

[6]
Modified ADS-Contract-system (ADS-C) was chosen for the surveillance of the helicopters operating outside radar coverage, based on ICAO's ADS-concept (technical specification in RTCA DO-212, ATN, data link via INMARSAT).

[8]
The M–ADS system primarily supports a data link utilising AMSS, however it can be expanded (CMU) to support HFDL (HF Datalink) and VDL (VHF Datalink).

[12]
In the M-ADS project, all helicopters are fitted with a low-gain (Aero-L) AES. Aero-L is fully compliant with the ICAO AMSS SARPS. Data-3 packet data service is used by M-ADS.

[8]
ADS Function is implemented in accordance with RTCA/DO-212. The ADS Function has implemented a special algorithm, which is used in situations of data link loss. To avoid congestion and obsolete messages the newest periodic report replaces any previous periodic report queued for transmission. Also the newest way point event report replaces any previous way point event report. All altitude and vertical rate event reports are buffered and are never considered obsolete.

[8]
The ADS reports are transmitted automatically without pilot action. In addition the pilot has the capability to initiate an emergency mode. In this mode ADS reports are transmitted at a high fixed rate to support ATC alerting procedures and assist search and rescue operations.

[8]
CMA is based on the RTCA/DO-223. Only the Context Management Log-on Function (CMLF) is implemented in M-ADS (as defined in RTCA/DO-223), but has added some functionality. The M-ADS airborne equipment performs the CMLF with a configurable set of ground systems (currently maximum 4).

> *NOTE: The added functionality allows the CMLF to restart when no ADS contract has been set up by the ground or when an ADS connection has been disconnected. The amount of time that shall elapse before the CMLF restarts is configurable, and may differ for different situations.*

[8]
Summary of Modifications of M-ADS vs. ADS:

- M-ADS Unit is smaller than the ARINC 745 form and fit specifies and does not follow the in ARINC 745 aircraft-wiring interface.
- M-ADS system does not support lateral deviation change event, Intermediate Projected Intent Group (Optional from RTCA/DO-212) and Fixed Projected Intent Group (Optional from RTCA/DO-212)
- Flight ID is not available from all the helicopters, and a fixed artificial Flight ID is compiled and supported by the ADS Unit in such cases.
- The M-ADS system has an extra 3 octet size down link message group (SSR group) defined as an optional group in addition to the groups that are already defined in RTCA/DO-212 and ARINC 745. The SSR code is used in lieu of the Flight Id to identify the helicopters for North Sea operation.

[6]
Published ADS area (AIP) includes the Class G (non-controlled-) airspace between land and the main oil fields from 1500 ft MSL (Mean Sea Level) to FL 85.

[9]
Aircraft not equipped with M-ADS is requested to fly outside ADS areas. During a possible crossing of an ADS area, the aircraft pilot in command is asked to contact the applicable Air Traffic Control Centre before initiating the crossing.

[9]
In ADS areas there will be a track system defined by VOR radials at the land bases. This system is intended to be used for traffic flying with dispensation from M-ADS requirements, and as a back up system for M-ADS technical failures.

[9]
The use of M-ADS during provision of Flight Information Service does not relieve the aircraft Pilot in Command of any responsibility, and he/she must make the final decision when it comes to any suggestions towards changing the flight plan.

[9]
M-ADS Operational position update rate is 30 seconds (normal), 20 seconds for tracks within 20 NM being separated vertically by less than 1000 ft, 10 seconds for operations below 700 ft and tracks within 10 NM being vertically separated by less than 1000 ft.

[7]

During landing, initial "en-route" reporting rate is increased below 700 feet and decreased again upon "Weight-on-wheels" (parking-) event. In the opposite direction first the slow "parking" update rate is used, after take-off several event-driven reports are typically contracted, above 700 feet "en-route" periodic contract is used, combined with the event contract in the case of abnormal descent. Additionally, emergency contract is initiated if the rate of descent exceeds the predefined value. During emergency state the reporting rate is automatically increased and additional data (i.e. SSR code) are downlinked.

NOTE: This sample scenario demonstrates how different ADS contract types may be combined together to achieve pre-defined operational goals.

A.16.5 Key Requirements Identified in M-ADS Helicopter Operations Project

[8]
M-ADS system requirements:

1. Radar look alike surveillance (near real time 4-D position information) by air traffic controllers from sea level and up.
2. No special purpose infrastructure or other means of technical installations shall be needed on the ground, except for display and communication systems at the ATC centres.
3. Only (bi-directional) **data** need to be transferred between aircraft and ATC.
4. The implemented surveillance system shall follow the ICAO FANS concept.

[8]
Standards applicable to M-ADS:

1. ADS compliant with RTCA/DO-212 with some minor modifications
2. Context Management Application following RTCA/DO-223
3. ATN-compliant Air-Ground data communication (INMARSAT/ Data 3 data link, X.25 terrestrial communication links).

[8]
It is required that both the ADS Function in the aircraft and the ADS Process at the ATC Center use a common time reference.

NOTE: A practical means of this is the GPS clock if available in the aircraft and at the ATS Centre. However, in case of GPS failure or other outages, time is collected from the RNAV / FMS computer, which provide GMT. The Figure Of Merit reflects the time reference change.

[9]
A standard ADS plot is based on a periodic contract with the normal update rate of 30 seconds, but the Air Traffic Controller can change the rate.

[9]
Providing of Flight Information Service (FIS) is based on a display unit to present the traffic picture to the Air Traffic Controller in his working position which include both radar and ADS aircraft position symbols. Outside radar coverage, and in case of radar failure, only the ADS position symbol will be presented, while inside radar coverage, only the radar-position

symbol will be presented. The transition between radar and ADS must be automatic, and the symbols must clearly indicate which source the position symbols are based on.

[9]
Minimum criteria for providing Alerting Service when using M-ADS is that the alarm signals must be presented by the Air Traffic Controller in his work position, and that the display unit with position symbol is easily accessible.

[9]
Before ADS service can be provided, the aircraft must be ADS identified and the identification must be verified. The ADS identification must be maintained as long as the ADS service is provided. When the aircraft is ADS identified, the aircraft must be informed before flight information based on M-ADS information is communicated.

[9]
It is necessary for the Air Traffic Controller to at all times be aware of which flights receive service based on use of radar and which flights receive service based on ADS, and to know the difference between these two services.

[9]
If traffic information regarding ADS identified traffic is given to radar-identified traffic or vice versa, special considerations must be made with regards to system accuracy and update rates in conjunction with each other. The pilot should also be informed about this.

A.16.6 References

6. M-ADS/ Modified Automatic Dependent Surveillance/ presented by Stein L. Clason, Norwegian CAA/ The proceedings of the ATN’99 Conference, IEE, London, Sept. 1999
7. Modified (Expanded) Automatic Dependent Surveillance-M-ADS- As Implemented in Norway/ presented by Kjell Arne Kamben, Norwegian CAA/ The proceedings of the ATN’99 Conference, IEE, London, Sept. 1999
8. NCAA/ ADS for Helicopters in the North Sea/ M-ADS (Technical description of the system), Ver. 1, 15. Oct. 1998
9. NCAA/ M-ADS Operational Concept, OK1- REV A, 12.10.1998

A.17 NUP

A.17.1 Introduction

NUP (North European ADS-B Network Update Programme) is a TEN-T DGVII European Project. It is the follow-up of two previous projects: NEAN (North European ADS-B Network) and NEAP (North European CNS/ATM Application Project).

The main partners are Swedish CAA, DFS, Danish CAA, SAS, Lufthansa, Aerospatiale Matra Airbus and Sofreavia/DGAC. A co-ordination has also been established with the Eurocontrol ADS Programme.

The project is split into two phases, phase 1 focusing on planning and development and phase 2 on implementation. Phase 1 started in August 1998 and lasts until June 2001. Phase 2 is planned to start in July 2001.

The cornerstone of NUP is the use of VDL Mode 4 in air/ground applications.

A.17.2 Background

NEAN and NEAP are DGVII European projects (respectively TEN-T and Fourth Framework Programme), which are now finished. The main partners were Swedish CAA, DFS, Danish CAA, SAS and Lufthansa.

The overall objective of the NEAN project was to develop, evaluate and demonstrate new technologies for data-links and networking (i.e. STDMA), and thereby contribute to the implementation of a network for CNS in the provision of Air Traffic Management in Europe. An experimental system was established including interconnected ground stations, aircraft fitted with ADS-B transceivers and CDTI and ground vehicles equipped with ADS-B transceivers. The network has been used to monitor the FREER-3 flight trials performed by the Eurocontrol Experimental Centre.

NEAP can be viewed as an “application” extension of the NEAN project and utilised the ground and airborne infrastructure implemented in that project. Seven applications have been specified, developed, tested and evaluated: GNSS precision navigation capability for en-route and approach; on-ground situation awareness / taxi guidance; in-flight situation awareness; enhanced surveillance for ATC; ATIS-Broadcast; extended helicopter surveillance; and runway incursion monitoring.

NEAP can be seen as a first demonstrator based on the NEAN infrastructure whereas NUP should lead to operational results through Europe.

A.17.3 Objectives

The main objective is to establish an European ADS-B network based on global standards, with certifiable applications and equipment supporting new ATM concepts that can be put into operation.

A.17.4 Main results and on-going activities

A.17.4.1 Tiger Teams

One of the major activities within NUP is the definition of “Applications and procedures”. The goal is to identify some ADS-B based applications driven by operational needs and justified by benefits anticipated by the partners. The approach taken is to develop applications and procedures in local teams looking at different phases of flight, and later in the process to merge the various requirements and procedures. These teams are called “Tiger Teams” and involve some ATM actors (i.e. controllers and pilots). The establishment of the different teams has taken some time but at the end, seven Tiger Teams have been created, each of them addressing an application identified by the users.

Tiger Team	Application	Description / objectives
Stockholm / Arlanda	Delegated Airborne Separation for Approach, Take-Off and Climb-Out	Reduction of the separation in time closer to the runway occupancy time by delegating the responsibility for separation assurance from ATC to flight crews under certain conditions
Frankfurt	Extended Visual Acquisition	Extension of the current visual traffic acquisition prior to executing an instrument approach applying visual separation on final. The flight crew uses the CDTI to allocate and track the preceding aircraft more effectively
Paris / Charles De Gaulle	A-SMGCS	The goal is to enhance surveillance to provide the controllers with a more accurate and more complete knowledge of the ground traffic, hence enabling an improved traffic control service. In addition it could be envisaged to also work on the use of a CDTI on the ground to improve the pilots traffic situational awareness
Nice	Enhanced Visual Acquisition for see-and-avoid applied to IFR/VFR compatibility	Improvement of the IFR/VFR compatibility in classes D and E airspace through the use of an airborne Traffic Situational Awareness application, based on the use of ADS-B, additional broadcast technologies and a CDTI
Maastricht UAC	Delegated Airborne Separation in en-route airspace	Delegation by a controller to the aircrew of a cluster of two or more aircraft for the responsibility to maintain an assigned horizontal separation in managed airspace through the definition of the Cluster Control Concept
Copenhagen	Helicopter surveillance in non-radar airspace	Surveillance of helicopters flying from land to oil platforms in the North Sea
Reykjavik	Station-keeping in oceanic non-radar airspace	The Tiger Team is going to start the work late May 2000

A.17.4.2 Certification process

In parallel of the establishment of the Tiger Teams, the Certification work package has defined the certification process that will be used for the various applications developed by the Tiger Teams. Some templates of documents have been produced, mainly the Operational Environment Definition (OED) and the Operational Hazard Analysis (OHA), which are derived from the Operational Safety Assessment (OSA) methodology developed by RTCA-SC189 and EUROCAE WG53. Each Tiger Team has to fill the OED template. Then the OHA template will be developed by the certification actors, in co-operation with the Tiger Teams.

By the end of NUP phase 1, a SPR (Safety and Performance Requirements) and an ASOR (Allocation of Safety Objectives and Requirements) documents will be produced.

In the second phase of the project, it is planned to perform the Functional Hazard Analysis (FHA) for the air and ground segments based on the results of the certification activities of phase 1.

A.17.4.3 Air/Ground infrastructure

NUP phase 1 does not intend to replace the existing NEAN infrastructure, but to build a small ADS-B/VDL Mode 4 network in parallel to evaluate the concept and applications defined within the project. Therefore a limited number of ground stations will be developed. They should support primarily Surveillance and Navigation and be prepared for point-to-point Communications.

The definition of a ground architecture is studied. The goal is to develop a ground infrastructure concept supporting the applications developed by the Tiger Teams, based on experiences from NEAN. It will also embed growth mechanisms to handle future services and functions.

Another activity is to develop concepts for monitoring ATM networks running ADS-B and communications cross-multination borders, based on experiences from NEAN.

Potential ground broadcast services enabled by the use of VDL Mode 4 have been identified. The main work will be focused on TIS-B (Traffic Information Service – Broadcast) and it will be performed in conjunction with FARAWAY II and Eurocontrol ADS Programme. TIS-B is considered as a necessary service to address the transition phase before a large ADS-B equipage of the aircraft.

NUP will also work on the definition and validation of the GNSS augmentation capability of the VDL Mode 4 system, introduced by ICAO as Ground based Regional Augmentations Services (GRAS).

In preparation of the second phase of NUP, the issues related to the required frequency allocations for VDL Mode 4 are studied. This includes capacity analysis, planning criteria, interoperability with other VDL Modes, etc. So far, the existing NEAN frequency (136.950MHz) has been accepted by all European states as a potential VDL mode 4 frequency. All partner States have assigned this frequency throughout NUP phase 1.

For the airborne side, Aerospatiale Matra Airbus is studying an airborne architecture for commercial aircraft.
In addition, airborne equipment from the industry, which is designed for General Aviation and surface vehicles, will be developed to form the basis for certification activities and for validation of the different applications. These VDL Mode 4 units are expected to provide enough test data for the evaluation of the studied applications.

A.17.5 ATM key concepts and requirements identified

All the results are not yet available because NUP is a running project. However, some significant results have already been achieved.

The establishment of the seven Tiger Teams developing ADS-B applications (mainly ASAS applications) highlights the interest of users for ADS-B as a new perspective in the development of CNS/ATM applications.

The applications have been identified for their potential contribution in increasing mainly capacity, but also safety.

A pragmatic approach is followed by the Tiger Teams in the selection and the definition of the applications. They have not envisaged to work on long-term applications to address a current operational need.

Some Tiger Teams have selected short-term applications, which would mainly improve pilots' traffic situational awareness. The applications are relatively simple because they do not alter the current share of responsibility between controllers and pilots in the separation assurance process. However, they should not fully address the operational need, but they are defined as the preliminary stage before the development of more complex applications.

Some other Tiger Teams are directly working on more complex applications within NUP Phase 1. These are co-operative separation applications, which are mid-term applications. They are more complex and involve a partial transfer of responsibility from the ground to the air side.

This dual approach is complementary and should enable the operational implementation of these applications.

In addition to this operational aspect, NUP will also provide some technical results related to ADS-B. The development of ground and air equipment based on VDL Mode 4 should enable to evaluate the applications defined by the Tiger Teams. It can also provide a basis for other projects.

The objective of NUP is to develop applications which can be operationally implemented. Therefore, a full certification process has been set, based on RTCA/SC-189 and EUROCAE/WG53 methodology.

A.18 ODIAC/AIRSAW Task Force

A.18.1 Introduction

The ODIAC (Operational Development of Integrated surveillance and Air/ground data Communications) subgroup of EUROCONTROL identified that the definition on an Airborne Situational Awareness (AIRSAW) would be essential to Co-operative Air Traffic Management.

The ODIAC subgroup proposed the creation of the AIRSAW Task Force (TF), which was accepted by ODT (Operational requirements and Data processing Team). The AIRSAW-TF was subsequently created by the EATCHIP Project leader.

The AIRSAW-TF was tasked to define a concept and operational requirements for Airborne Situational Awareness services in a gate-to-gate perspective, ensuring ATC operational interoperability, including procedures and safety provisions.

Participants were operational experts representing Airspace users, Aviation industry, ECAC member States and EUROCONTROL. IFALPA had the leadership of the TF.

A.18.2 Objectives

The AIRSAW-TF objective was the determination of an operational concept and resulting requirements for Airborne Situational Awareness in view of achieving initial Co-operative ATM services to enhance the productivity of the European ATM system.

The tasks identified in the Terms of References were:

- Develop the operational concept for the use of AIRSAW in the European airspace, considering the global applications of airborne surveillance and on the basis of an analysis of the consequences on Aircrew and ATC workload, responsibilities, procedures and legal aspects. Military aspects shall also be taken into account.
  Note: Monitoring of on-going work within ICAO ADS-P and SICAS-P, RTCA and EUROCAE and any other bodies as appropriate is necessary for the achievement of the task.
- Determine the gate-to-gate services and priorities resulting from the AIRSAW concept, and produce the service descriptions.
- Consider any available results of completed, on-going and forthcoming studies and trials.
- Co-ordinate with other appropriate EATCHIP bodies as necessary and identify any requirement for co-ordination with organisations outside EUROCONTROL (e.g. AEA, AEEC, EBAA, ERA, EUROCAE, EU, FAA, IACA, IATA, ICAO, IFALPA, IFATCA, RTCA, IAOPA and NATO).

A.18.3 Main results

The scope of the activities was considered very large, the AIRSAW concept encompassing Air Traffic Management Awareness (ATMAW), Air Traffic Situation Awareness (ATSAW) and Co-operative Separation services (Airborne Separation Assurance – ASAS). As a result, the AIRSAW-TF faced some working difficulties in achieving a common understanding of the way forward.

The AIRSAW-TF initiated activities to establish what could be the impact in particular areas, mainly on ICAO legislation, on related procedures and on air and ground responsibilities. It focused on developing a detailed and progressive operational concept that would include all aspects of functionality, application, legislation, air/ground responsibility and corresponding requirements.

AIRSAW-TF produced a deliverable document, the AIRSAW Operational Concept Volume 1. This is a high level document, which points out to the Aviation Community the benefits that may be achieved by its implementation.

The concept was presented and discussed at ODIAC 27 (9-11 November 1999) and the issues surrounding the concept, in particular those relating to delegation of separation to Aircrew, triggered many comments. In particular, the Aircrew Members of ODIAC considered that these issues have a considerable impact on their work and thus any continuation of work in this area shall only be contemplated provided that a significant commitment from Airlines and particularly Aircrews would be achieved within any kind of working arrangements.

ODIAC endorsed the concept, which has then been presented to ODT.

The AIRSAW Concept:

A.18.3.1 Background

The AIRSAW Concept is one enabler within the ODIAC Concept, which will facilitate the achievement of objectives of the OCD Target Concept and the ATM 2000+ Strategy.

The **OCD Target Concept** provided the ATM 2000+ Strategy with the general operational vision of ATM within the ECAC area for the year 2015, in which the anticipated benefits would be satisfied by directed, combined actions in several areas. The OCD Target Concept states that there will be:
"A collaborative and layered planning system, strategically co-ordinated and operating gate-to-gate, incorporating capacity management, and based on three airspace regimes with shared responsibilities for separation assurance involving changes to roles and responsibilities under-pinned by enhanced computer support.

Development of the future ATM network will not be technology-led and the aims will be to develop systems to solve current limitations, to sustain the forecast operational changes and to prepare a smooth transition to the challenges of the next century.

There is a general requirement for flight crews to be more aware of the surrounding traffic situation and environment. Air-ground integration also calls for the evolution of both the air and ground Air Traffic Control (ATC) elements and flight operations to be developed in harmony and collaboration."

The **ATM Strategy for 2000+** anticipates that there are areas in which potential sources of capacity can be found, in particular by improving the aircrew situational awareness, or through the provision to the flight crew and ATS of appropriate means and information that will permit some transfer of responsibility for separation assurance from the ground to the air. This transfer will increase controller productivity, flexibility and efficiency and is predicted to occur in two stages:

"***Limited Transfer** – The use of airborne conflict detection and resolution functions, packaged with a suitable cockpit display of information (CDTI), and in conjunction with improved navigational capabilities, will enable a limited transfer of the responsibility for separation from the ground system to the cockpit in prescribed circumstances, such as in-trail climbs and on one-way routes. Limited Transfer will lead to a reduction in the ATC workload associated with routine monitoring*."

"***Extended Transfer*** *– The use of Airborne Separation Assurance Systems (ASAS), with look-ahead capabilities of 6 to 8 minutes will support the extension of delegated separation responsibilities and autonomous aircraft operations. This can be allied to free route operations and support the introduction of designated 'free flight' airspace, where aircraft will fly optimised and fuel efficient user-preferred trajectories and separate themselves from other aircraft. While these operations are likely to be confined to low traffic density airspace, they will further enhance flight efficiency and flexibility. Extended Transfer will lead to a further reduction in the ATC workload associated with conflict search, problem-solving tasks and facilitate greater freedom for flights*."

A.18.3.2 "Airborne Situational Awareness" and "Separation Assurance"

Airborne Situational Awareness is the aircrew's knowledge of the aircraft's state and the external operational environment relevant to the flight. As well as information on the terrain, aircraft position and weather, a central component of the flight crew's decision process for the management of the flight includes aircrew's knowledge of the surrounding traffic situation in the air and on the ground (Airborne Traffic Situational Awareness - ATSAW) and of current ATM planning and constraints (Air Traffic Management Awareness - ATMAW).

Airborne situational awareness does not constitute separation assurance in itself. Nevertheless, taking advantage of the new sharing of information between the ground and the air, increased airborne situational awareness will be one of the essential enabler for the transfer of separation assurance tasks to the flight crew.

The transfer of responsibility for separation assurance will be enabled by airborne and ground ATM elements at four different levels.

- **Strategic level**: The ATS services, flight rules and institutional aspects, including legal liability, that will clearly define the roles and responsibilities of all the actors (e.g. States, ATS providers, airspace users, pilots and controllers). Flight rules will have to define the avoidance principles linked to airborne separation assurance, the airborne separation minima standards and possible new rules of flight for autonomous aircraft operations.
- **Tactical and operation level**: The procedures that will precisely define the allocation of separation assurance tasks between pilots and controllers, the conditions of applicability of airborne separation (e.g. type of airspace, IFR/VFR, radar or non-radar ATC environment), the contingency actions in case of loss of airborne separation capability, and the training of pilots and controllers for a correct use of these procedures and systems for airborne separation assurance.
- **Technical level**: The air and ground automation support that includes the airborne surveillance and separation assurance capabilities and the cockpit display of traffic and separation information, the elements of the ground ATM system that will handle the aircraft performing airborne separation tasks, and the air-air and air-ground communications support and protocols.
- **Safety level**: The relationship between the airborne separation assurance systems, their associated procedures and safety nets that will ensure the achievement of the overall required safety level for ATM.

A.18.3.3 Main benefits

The AIRSAW concept anticipates a level of airborne situational awareness that will enable:

- improved flight management;
- improved Airport Operations, in particular in low visibility conditions;

- safer operations in Unmanaged Airspace (UMAS);
- the Limited Transfer of responsibility for separation assurance in Managed Airspace (MAS);
- The Extended Transfer of responsibility for separation assurance in Free Flight Airspace (FFAS).

It will also contribute to improve safety for the flight crew, bring the benefits of improved safety, flexibility and efficiency to ATM and will contribute to the achievement of greater capacity within the ECAC area. By reducing fuel burn, it can also be expected to contribute to a reduction in the environmental impact of individual flights.

A.18.3.4 Utilisation stages

The AIRSAW concept is seen to be developed through three stages of utilisation.

- **Basic AIRSAW**: the principle is to improve Flight Management in general in all airspace by providing the flight with relevant information on the state of the aircraft, of its operating environment and of potential hazards to its safety. This information will be provided in a suitable manner, in which the ability to “See and Avoid” and the performance of visual procedures are improved. In UMAS responsibility for separation will remain with the flight crew (as it is today outside controlled airspace). In Managed Airspace (MAS) there will be **no delegation** of any separation assurance tasks to the flight crew.
- **Intermediate AIRSAW**: the principle is to enable ground ATM to benefit from the capability of the flight crew, as the result of increased airborne situational awareness, to accept the delegation of responsibility for some separation tasks whilst in MAS (**Limited Transfer**). (for example: station keeping, in-trail climbs)
- **Advanced AIRSAW**: the principle is to enable ground ATM to benefit from the capability of the flight crew, as the result of increased airborne situational awareness and airborne separation assurance capabilities, to accept the full transfer of responsibility for separation assurance in FFAS (**Extended Transfer**).

The Operational Concept for AIRSAW Volume 1 provides for each of these stages, a description of benefits, controller/flight crew responsibilities, main issues, data requirements and example.

A.18.3.5 Collateral issues

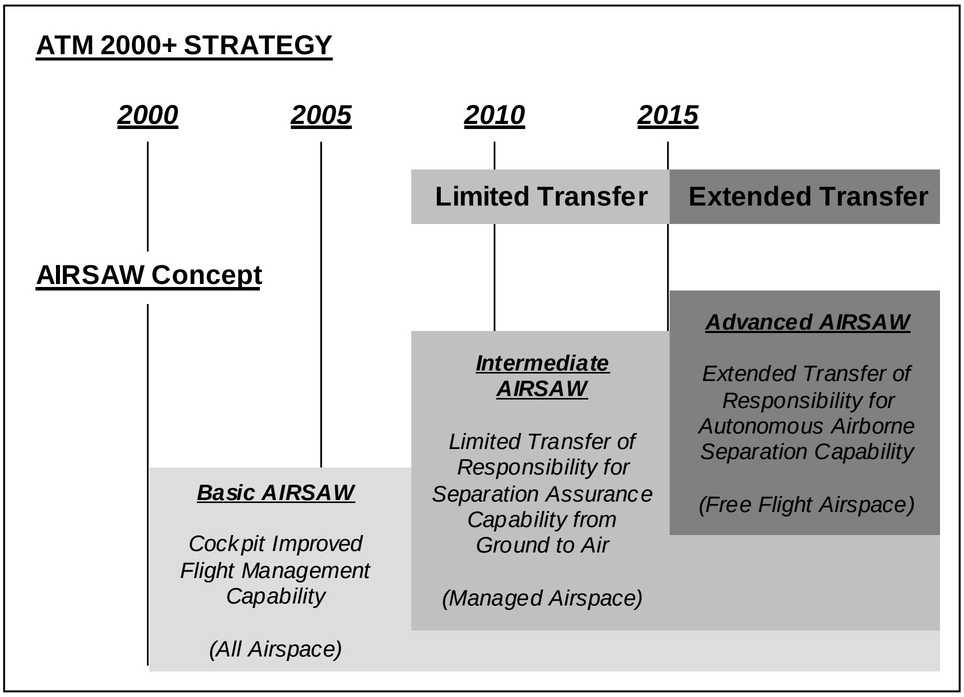
The AIRSAW Concept will also have an impact:

- **outside ECAC**, in areas where ATS are limited (e.g. in airspace with only Advisory Services) the use of AIRSAW has a great potential to provide significant benefits for safety and efficiency of air traffic operations, for example, in support of Traffic Information Broadcast by Aircraft (TIBA);
- **on military operations** because of the transfer of separation assurance. Whereas the use of Intermediate AIRSAW is not seen as a concern, the co-joint use of airspace in which Advanced AIRSAW is being utilised is seen as challenging to the military and new procedures will be needed.

A.18.4 ATM key concept and requirements identified

An Operational Concept for Airborne Situational Awareness is available, based on the OCD Target Concept and the ATM 2000+ Strategy. It addresses the relationship between the various levels of AIRSAW utilisation and of transfer of responsibility for separation assurance.

The figure below shows the possible introduction of the three AIRSAW stages in relation to the evolutionary steps defined in the ATM 2000+ Strategy. It should be noted that the introduction of Basic AIRSAW is not linked to an identified step within the Strategy.



The three stages are not fully sequential, i.e. the introduction of the intermediate AIRSAW will not replace the basic AIRSAW but it will come in addition to the first one.

Four different levels for airborne and ground ATM elements to enable the transfer of responsibility for separation assurance are identified: Strategic, Tactical and Operational, Technical, and Safety.

For each stage, the document provides a description of benefits, controller/flight crew responsibilities, main issues, data requirements and example, and some information about collateral issues, mainly the impact on military operations.

Finally, the production of this document has highlighted the difficulty for the various ATM actors to converge to a common position on ASAS and the crucial importance to address correctly the issue of transfer of responsibility in the separation assurance process.

A.19 Ohio Valley ADS-B (Cargo Airlines Association)

A.19.1 Introduction

In 1996 the Cargo Airlines Association (CAA) began a program to develop an Enhanced Collision Avoidance System (ECAS) based on ADS-B technology in an effort to achieve an improved separation tool. The CAA ADS-B Program consists of three phases:

- Phase I is intended to achieve fleet-wide installation of an ADS-B based CDTI system for use as a pilot aid to visual acquisition of other traffic for see and avoid. The objectives of the Phase I OpEval are three-fold: (1) to demonstrate ADS-B technology, (2) to evaluate specific air-air and air-ground applications, and (3) to develop a wide support base for the advancement of ADS-B implementation.
- Phase II is intended as a software upgrade to the Phase I system to provide conflict detection functionality.
- Phase III is intended as a software upgrade to the Phase II system to provide resolution advisories, resulting in full conflict detection and resolution (CD&R) functionality.

The Cargo Airline Association (CAA) is leading the development of ADS-B in commercial jets and is co-sponsoring the Ohio Valley demonstrations with the FAA. UPS Aviation Technologies developed and certified ADS-B datalinks and Cockpit Displays of Traffic Information (CDTI) in accordance with the specifications developed by the CAA participants.

The Ohio Valley evaluation is built on stakeholder participation in the planning and conduct of the evaluations

A.19.2 Results/Objectives

A.19.2.1 Introduction

- There are three Operational Evaluations (OpEval) planned.

A.19.2.2 OpEval1

- During 1999, Airborne Express, Federal Express and United Parcel Service installed ADS-B systems in four aircraft each. Those aircraft participated in an Operational Evaluation (OpEval) of ADS-B on July 10, 1999. Throughout the rest of 1999, these aircraft flew in revenue service with active ADS-B systems, allowing the FAA to collect and evaluate data for scientific evaluation. Also participating in the July 10 OpEval were ADS-B equipped aircraft from the FAA Technical Center, The U.S. Navy, NASA, Rockwell Collins, Honeywell, UPS Aviation Technologies and Ohio University.

- The 1999 Operational Evaluation and in-service evaluations demonstrated ADS-B’s ability to improve pilot situational awareness and to improve the pilot’s ability to safely maintain aircraft spacing both en- route and on final approach to landing. The Cargo Airline Association has described these ADS-B System Trials as a success, and believes that ADS-offers a wide range of benefits.

- A NASA Human Factors team has evaluated the system during the trials and suggested several changes to the system to make it more effective. UPS Aviation Technologies is incorporating NASA's suggestions in a new version of ADS-B hardware and software that includes conflict detection tools for the pilot and will seek certification for the system in Summer 2000. UPS has already committed to installing the system in its entire fleet of more than 230 aircraft.

- The new ADS-B software and hardware contains algorithms for airborne conflict detection. It will provide pilots visual and audible cues when it determines that there is a potential conflict with other equipped aircraft. The system will be capable of making this determination at greater distances than is possible with current collision avoidance equipment.

- There has more recently been a large-scale test of ADS-B, with 24 aircraft and one surface test van equipped with this advanced technology having participated in an Operational Evaluation. ADS-B data were fused with radar data from a surveillance radar facility and displayed on an Air Traffic Control workstation.

- During these trials, pilots demonstrated a variety of ADS-B-enhanced procedures. These included the ability of CDTI to help pilots identify other aircraft traffic and improve the efficiency of airport arrivals and departures under visual-flight conditions. Other trials were performed to determine how ADS-B displays can help pilots carry out air traffic control sequencing instructions and improve their awareness of other aviation traffic on airport taxiways and runways.

- NASA Human Factors investigators took part to determine how pilots interacted with the new equipment. ADS-B data received by each aircraft were recorded for later analysis, and the findings will be reported to the CAA and FAA later this year. Initial reports suggest that the ADS-B system performed as expected.

- Results of OpEval 1 are available in a report prepared by the entity co-chaired by the Cargo Airline Association Automatic Dependent Surveillance – Broadcast (ADS-B) Steering Committee and the Federal Aviation Administration's (FAA) SafeFlight 21 (SF21) program office. This report does not give a detailed evaluation of the ground system.

- Flight activities during OpEval were prioritized to focus on near-term CDTI applications that may provide benefits in a relatively short time period with few changes to current ATC procedures, other than flight crew procedures to utilize aircraft call sign. The scenarios were designed to assess crew performance, operational procedures/benefits, and data link technical performance. The CDTI applications were prioritized in the following manner (from highest to lowest priority):

    - Evaluate Enhanced Visual Acquisition for "See & Avoid"
    - Evaluate Enhanced Visual Approaches
    - Demonstrate Airport Surface Situation Awareness
    - Demonstrate Enhanced In-Trail (or Lead) Climbs/Descents
    - Demonstrate Station Keeping
    - Demonstrate Departure Spacing
    - Demonstrate Final Approach Spacing

- The initial CAA CDTI implementation was evaluated with respect to the near-term applications listed above.

- For the Enhanced Visual Acquisition evaluation, the mature operational concept and associated CDTI requirements were tested. Both pilots and controllers felt the CDTI augmented the visual acquisition task and improved pilot awareness of surrounding traffic. No significant problems with respect to the operational approval of this application for traffic environments similar to OpEval were revealed. One potential issue that was raised, which needs to be addressed as part of future CDTI training programs, is that of flight crews initiating unwarranted requests from ATC.

- For the Enhanced Visual Approach Evaluation, the CDTI requirements as outlined in the mature operational concept were tested. The results have revealed operational, although not statistically significant, performance benefits in the form of enhanced spacing awareness and a potential reduction in the misidentification of aircraft called out by ATC. As with Enhanced Visual Acquisition, both pilots and controllers felt the CDTI augmented flight crew performance during visual approaches and no significant problems with respect to the operational approval of this application for traffic environments similar to OpEval were revealed. The remaining applications were demonstrated and the findings will be fed into future operational concept development and evaluations.

- Although the airborne applications were the primary focus of the Operational Evaluation, the ground system demonstrated the potential to support air – ground ADS-B applications. The ADS-B Minimum Aviation System Performance Specification (MASPS), RTCA DO-242, identifies a number of potential near-term ADS-B Air Traffic Services surveillance applications. Many of these are reflected in the Safe Flight 21 near-term plans.

- It is anticipated that technologies demonstrated as part of the ground system architecture can evolve to support ADS-B applications in all domains. In the terminal and en-route domain, in particular, the potential to evolve existing legacy systems will be considered. This approach is being taken in Alaska's Project Capstone.

- The project intends that this evolution should be tied to high priority applications based on airspace user consensus. It is anticipated that the next steps will focus on increasing terminal capacity, improving airport surface safety and efficiency, and providing "pseudo-radar" coverage in non-radar airspace. It is expected that this will evolve to support more applications in all domains.

- US Naval Air Systems Command also took part in OpEval1. As a consequence of this, it has recently commissioned a research program into ADS-B using Mode-S extended squitter, which will perform an operational demonstration of prototype avionics.

A.19.2.3 OpEval2

- In late October 2000, the Cargo Airline Association and the FAA will stage OpEval-2 in Louisville, Kentucky, to develop and evaluate avionics and procedural modifications needed to support operational approval for the following Safe Flight 21 Master Plan Applications:

  a) Approach Spacing
  b) Departure Spacing/Clearance
  c) Runway and Final Approach Occupancy Awareness
  d) Airport Surface Situational Awareness

- The goal will be to evaluate air traffic controller use of ADS-B in the terminal area environment, concentrating on the above four applications.

A.19.2.4 OpEval3

- OpEval-3 is planned for Spring 2001, and the intended site is Memphis International Airport. The objectives of OpEval-3 are to:

    a) Develop and evaluate avionics and procedural modifications needed to support operational approval for the SF21 Master Plan application #7.1: Enhanced Presentation of Surface Targets to Controller.
    b) Enhance Airport Surface Management by facilitating better co-ordination among, and communication between, surface traffic management operations within airline operations, air traffic control and airport operators.
    c) Limited demonstration to key industry participants.

- The FAA Safe Flight 21 Program Office is installing a suite of surface and terminal area sensors, displays and integration equipment consisting of a Sensis Airport Target IDentification System (ATIDS), the Volpe Center Terminal Automation Fusion Server and Surface Surveillance Fusion Server (SSFS), with displays in the FAA ATC Tower and FedEx and Northwest Airlines Ramp Control Towers.

- ATIDS is a transponder multi-lateration system that tracks and identifies all ADS-B 1090 MHz, Mode S and ATCRBS (Mode A/C) equipped aircraft.

- Two fusion servers form a Surveillance Automation System that combines data from the ASR-9 Terminal Radar, the ARTS-IIIA Terminal Automation System, the ASDE-3 Surface Radar, and the ATIDS to provide aircraft position, aircraft ID, and incursion alerts to the user. The combined (or fused) data from these four sensor sources and the flight identification information from the ARTS-IIIA is provided for display in the FAA ATC Tower and FedEx and Northwest Airlines Ramp Control Towers.

A.19.3 Key Concepts and Requirements Identified in this Project

The first operational evaluation has centred on ADS-B applications, the CDTI and flight procedures. Although the data link ground station has the capability to host the three current data link contenders, VDL Mode 4 was not tested. The results of the operational evaluation should validate the CDTI concepts of SC-186.

There is considerable support for CDTI in the US. One noted minor problem observed was the display clutter in the terminal area.

A.19.4 References

1. CAA Press Release, Washington, D.C., July 12, 1999
2. Phase I – Operational Evaluation Final Report, Cargo Airline Association (CAA) ADS-B program, FAA Safeflight 21 Program, April 10, 2000.
3. ADS-B website: www.ADS-B.com

A.20 PETAL II

A.20.1 Project Objectives

[10]
PETAL-II is a continuation of PETAL, the Preliminary EUROCONTROL Test of Air/ground data Link. PETAL II focuses on the validation of the operational concept, operational requirements and operational procedures for the EATCHIP- III air/ ground data link, also supporting the operational transition from EATCHIP- III to EATMS and the establishment of UAC Maastricht as an operational system.

[11]
All PETAL-II services are based as far as possible on the ODIAC datalink service definitions.

[11]
PETAL II focuses exclusively on the operational aspects of air/ground datalink in ATC, complementing the various technology-oriented trials and using the most practical and expeditious technical means available to achieve Project objectives. The PETAL-II initial partners and infrastructural components focus on the NEAN infrastructure. The follow-on partners will add other technologies such as ATN/VDL2, FANS-1/A and Mode S-specific datalink.

A.20.2 Methods Used

[11]
PETAL-II datalink services are used during **flights with commercial aircraft** conducting routine operations in controlled airspace **above FL245**. Initial operations began in June 1998, with commercial flights from Lufthansa and SAS (other airlines will be involved later in the project).

*NOTE: PETAL II focuses to the **continental en-route** aspects of the A/G data link. TMA and Airport environments are currently outside of the project scope, but there are some joint reporting agreements with other projects concerned with TMA or Airport applications.*

[12]
The methods of capturing the requirements data for PETAL included **questionnaires and interviews** for aircrew and controllers, project and systems development staff **observations**, as well as the **post-flight analysis** of message traffic.

A.20.3 Main Results

NOTE: PETAL II is an ongoing project, so the final report with a summary of results is not available yet. Here are some important results of the PETAL I project [12] related to the operational aspects.

[12]

Controllers and aircrew suggested a number of potential operational benefits for ATC and aircraft operators through controller/aircrew datalink exchanges.

[12]
Controllers and aircrew concur that the primary use of datalink in the near term is for ‘strategic’ exchanges. Regardless of the potential delivery times, controllers generally do not believe datalink to be suitable for tactical situations.

[12]
Both aircrew and controllers expressed concern over loss of the party line.

A.20.4 Key Concepts Identified in PETAL II Project

NOTE: Because of traceability some references for concepts and requirements include the chapter of the original document [12]

[11]
PETAL II will implement the following A/G datalink services: **DLIC, ADS/FLIPCY, ADS/CAP, CPDLC/ACM, CPDLC/ACL (CIC), CPDLC/*AMC (and eventually CPDLC/CTC).***

NOTE: Neither Petal II [10] nor PETAL IIe currently intend to deploy the CTC service.

*NOTE: The above service list is applicable to all (NEAN-, FANS-1/A-, ATN-) PETAL II technological branches. PETAL IIe **Baseline 1** ATN datalink services [12] correspond to the above list.*

In addition to the above, PETAL-II partners utilising the VDL-4 prototype branch (NEAN) also use ADS-Broadcast (ADS-B) for the **B-DAP** service.

[12] [1.2.1 Operational Objectives]
The Baseline 1 air traffic services introduce a reduced set of the International Civil Aviation Organisation (ICAO) ATN controller/aircrew messages, focusing on those with the highest potential **for reducing the voice communications workload and voice channel congestion, enhancing cockpit and control sector co-ordination’s**. The ATS provider also utilise Automatic Dependent System **(ADS) to automatically receive the flight’s intended profile**, so that ATM specialists are fully aware of flight intentions so as to improve service to the flight.

[12] [3.1.1 Separation Minima]
In this initial stage, it is **not anticipated to reduce separation minima nor to immediately adapt airspace use and capacity** according to the Baseline 1 services provided by data communications.

[12] [1.2.3 Operating contexts]
Aircrew/ controller data link exchanges shall be in the context of strategic ATC situations only. Strategic ATC situations for the purposes of Baseline 1 ATS involve routine or high frequency types of transactions, non-critical communications, and do **not** concern the tactical separation of aircraft for immediate safety reasons.

[12] [4.1 Data Link System Operational Principles]

Digital communications are intended to serve as a **supplementary communication means** as designated for the operation being conducted where radar surveillance and ground interrogation (Mode C) service is provided**. Voice communication is required at all times.**

[11]
The PETAL II functional architecture has been specifically designed to provide common functional behaviour from the operations and FDPS perspectives, for datalink exchanges with aircraft using both ATN and non-ATN communications infrastructures.

A.20.5 Key Requirements Identified in PETAL II Project

[11]
Air, ground, and communications systems implemented in accordance with this specification shall be compliant to ICAO Standards And Recommended Practices (SARPS) for the ATN, Version 2.3 (ICAO doc 9705-AN/956, FIRST EDITION - 1998), except where explicitly stated otherwise in these specifications.

[11]
All PETAL-II services are based as far as possible on the ODIAC datalink service definitions. The operational data contents of messages, and the operational procedures, system logic and events surrounding the use of those messages, are in accordance with ICAO doc 9705 for Context Management / Data Link Initiation Capability (CM / DLIC), Controller/Pilot Data Link Communications (CPDLC), and Automatic Dependent Surveillance (ADS), wherever possible and for all branches of PETAL-II.

[11]
The operational application of datalink services shall remain at all times under the exclusive control of the air traffic controllers and aircrew involved.

[12]
Controllers and aircrew firmly require logical responses in support of their datalink exchanges.

[12] [1.2.3 Operating contexts]
Controllers and aircrew shall have access to both the voice and data communications capabilities, and the application of air traffic services provided by data communication shall subject to the judgment of the controllers and aircrew involved. Procedures shall be in place to revert to voice radiotelephony to resolve any conflicts.

[12] [4.1 Data Link System Operational Principles]
In all cases, voice instructions and acknowledgments should supersede data link instructions and acknowledgments.
Services and procedures should be provided to ensure the preservation of situational awareness for both data link and non-data link equipped aircraft and ground facilities.
Aircraft shall be under the control of only one ATC unit at a time, whether or not data link applications are being used.

[12] [4.1.1 Airborne System Operational Principles]
Operational exchanges of ATS over data link shall only be possible following successful completion of the DLIC service.
Airborne systems shall provide addressing and flight plan correlation data to each ATSU involved in the intended flight, or portion of flight where data link will be used, through the

DLIC service. Baseline 1 ground systems shall not be required to forward or exchange aircraft addressing data.

[12] [4.1.2 Ground System Operational Principles]
Ground systems shall have full control over controller/aircrew message exchanges. Control shall be based on operational data type.

[12] [4.2.2 Aircrew Procedures]
Prior to take-off, the aircrew shall input the current flight plan and other data into the appropriate airborne systems to support Baseline 1 ATS.
Aircrew shall manually trigger log-on/flight plan association in accordance with the DLIC service description.
Regardless of the method used by the controller to initiate transfer of voice communications, and whether or not the aircrew uses data link to establish initial contact with a new ATC sector, aircrew shall use standard voice procedures to complete the transfer of voice communications from one ATC sector to another. If the "monitor" instruction is used, voice contact is not necessary.
All aircrew-initiated exchanges shall remain at the discretion of the aircrew involved.
Aircrew shall monitor appropriate voice frequency.

[12] [4.2.3 ATC Procedures]
Data Link will take place if sector traffic levels permit, at the discretion of the Current Radar Controller.
The Current Radar Controller may start and/or stop data link sessions at any time at his own discretion.

[12] [5.1.2.1.3 Airborne Equipment Functionality]
Airborne system shall provide **at all time** VHF air-ground voice communication capability.
Airborne system should be designed such as when operating a data link system, there should be no increase in pilot in head-down time that would adversely affect safe operation.
The airborne system should provide the aircrew with the capability to respond to ATS messages: review, validate, and acknowledge any operational messages being delivered or received. In addition, the flight crew should have the capability to clear, list, select, edit, store, and retrieve ATS messages sent and received. A desirable option would be the capability to transfer appropriate flight crew approved information into other existing flight management functions.

[12] [5.1.2.3 ATC Automation]
The ground system should provide controllers with flight plan indications of data link capability as well as display indications of data link sessions and eligibility.
The ground system initially contacted by the aircraft should be able to pass the necessary aircraft address information to another ground station via ground/ground communications links (ICAO).

> *NOTE: It has been stated in the same document (4.1.1.3) that " Baseline 1 ground systems shall not be required to forward or exchange aircraft addressing data".*

[12] [5.1.2.4 Controller Interface]
The controller HMI should provide the controller with the capability to respond to messages, to issue clearances, instructions, and advisories and to request and provide information as appropriate. In addition, the controller should have the capability to clear, list, select, edit, store, and retrieve ATS messages sent and received.

The controller HMI should be designed such as when operating a data link system, there should be no increase in controller in head-down time that would adversely affect safe operation.

A.20.6 References

10. PETAL II Project Definition Document, EUROCONTROL OPR.ET1.ST05/2000/P2/3
11. PETAL II End-to-End Trials Specifications, Ver. 3.2, EUROCONTROL DED2/OPR/ET1/ST05/2000/P2/7
12. Operational Environmental Definition (OED), EUROCONTROL OPR/ET1/ST05/2000/P2/21
13. PETAL Final Report, EUROCONTROL DED2/OPR/ET1/ST05/2000/3

A.21 PHARE

A.21.1 Objectives

The PHARE Programme ran throughout the 1990s and involved the collaboration of a number of European ATM research organisations under the overall auspices of Eurocontrol.

Motivation for the programme was borne from the realisation that demand on the European ATC system was beginning to outstrip the scope for increasing its capacity by incremental improvements. To address this, it was felt that fundamental changes to the basic ATM process, and to the technologies which underpin it, were required.

The far higher degree of air-ground integration achievable with new technology has been, and still is, widely believed to be the key to a quantum leap in airspace management capacity. The PHARE Programme aimed to investigate this hypothesis by the development of advanced computer-based tools and by conducting a series of experiments using these. The primary objective was to obtain scientific results which quantitatively demonstrated the benefits of the PHARE concept.

A secondary objective of the programme was the promotion of synergy from general pan-European ATM collaboration.

Overview of PHARE 4D Routeing Concept

The initial proposal for a 4D route comes from the aircraft itself and will be based on its choice of preferred cruise level and climb and descent profiles. This initial proposal is sent to the ground ATC station using the datalink. Should the ground station be unable to approve the route (eg. due to conflict with established traffic) then it can suggest specific changes to it again via datalink.

Once a suitable trajectory has been agreed, the ground ATC station may give the aircraft approval to fly it by up-linking a contract. The contract identifies a 4D volume of airspace allocated to the aircraft and is sometimes referred to as *the tube* but is more accurately visualised as a 3D bubble moving along the trajectory with time.

Ideally, the contract for a 4D equipped aircraft will cover its entire flight. However, in recognition of the realities of today’s airspace management techniques, it is likely that the contract will be issued for 20-30 minutes ahead and then extended as the flight progresses.

As long as the contracted aircraft remains inside its tube then it can expect no subsequent interference from air traffic control for the duration of the flight.

A.21.2 Methods Used

The programme consisted of a continuous development phase punctuated by three large-scale experiments or PHARE Demonstrations (PDs) as they were called.

PD/1 focused on the use of increased air-ground integration in the en-route phase.
PD/2 focused on operation within the TMA.
PD/3 focused on all phases of flight and embraced multi-centre working.

PDs 1 and 2 were considered appropriate to the year 2000 time frame; whereas PD/3 was aimed at 2010 and beyond.

A.21.3 Main Results

A.21.3.1 Experimental Flight Management System – EFMS

Throughout the PHARE Programme, the EFMS demonstrated the feasibility of planning and executing detailed 4D trajectories to a high level of accuracy. Navigational performance was shown to be very good. Predictions were shown to be accurate but subject, of course, to the accuracy of the supplied meteorological predictions. Arrival times were typically within a few seconds of the prediction.

A.21.3.2 Airborne Human Machine Interface – AHMI

The AHMI developed as the programme progressed and a variety of different styles of operation were tried. By the end of the programme, much of the EFMS control functionality, including the negotiation process, had been transferred from the CDU to the EFIS. Route editing, performed using drag and drop techniques with a roller-ball, proved intuitive and popular with the air-crew.

Using the EFIS, pilots reported a welcome reduction in flight-deck activity during critical phases of flight, particularly during the arrival phase.

Although now extended to a twin crew fit (ie. Two EFISs and two CDUs), more work is required before the AHMI can genuinely support co-operative twin-crew operation.

A.21.3.3 Ground Human Machine Interface – GHMI

Although there were initial difficulties in getting controllers used to the new technology and the way in which information was presented to them, the overall conclusion regarding the GHMI was very positive. Like any new system, once the initial transition had been overcome, the users became increasingly comfortable with the GHMI and, in particular, came to appreciate its overall consistency.

A.21.3.4 PHARE Advanced Tools – PATs

Most of the PHARE Advanced tools seemed to perform well but, in particular, the Highly Interactive Problem Solver (HIPS) seemed particularly well received. Controllers soon got used to using it as an aid to resolving conflicts.

Other ground tools also worthy of note are the Conflict Probe (CP) and Flight Path Monitor (FPM). The Trajectory Predictor (TP) provided an essential service but was not a tool which the controllers needed to interact with directly.

The use of an established set of CMS Application Program Interfaces (APIs) proved invaluable during the development of the PATs tools.

A.21.4 Key Concepts and Requirements

A.21.4.1 Strategic 4D Routeing and Negotiation

The PHARE Programme demonstrated beyond doubt the viability of strategic 4D routeing based on air-ground negotiation and 4D clearances. It showed that a suitably equipped aircraft could reliably be trusted to follow an agreed trajectory lasting for several hours and that, on this basis, entire flights could be flown without interference from ATC.

The concept of a 4D volume of airspace allocated to 4D-equipped aircraft proved to be very successful and by the end of the programme was readily accepted by air-crew and controllers alike.

A.21.4.2 Area Navigation – RNAV

The use of accurate RNAV allowed routeing based on ground tracks and constant radius turns and greatly simplified the entire navigation process.

A.21.4.3 Sectorisation

The traditional method of overcoming increasing controller work-load has been to introduce smaller and smaller sectors. The concept of 4D routeing, trajectory negotiation and contracted airspace is based on a strategic approach to air traffic management rather than today's tactical approach and benefits from large sectors which allow longer 4D clearances.

A clear conclusion from PHARE was that controllers could comfortably manage larger sectors with increased traffic levels when handling predominantly 4D-equipped aircraft.

A.21.4.4 Datalink

Although it proved possible to develop an ICAO-compliant aeronautical telecommunications network, the reliability and performance of the satellite air-ground datalink proved insufficient to demonstrate the full capability of the PHARE concept.

A.21.4.5 Quantitative Results

The, hoped for, quantitative evidence of resultant increases in air-space capacity proved difficult to obtain due to a variety of mitigating circumstances. Nonetheless, experience with 4D routeing and greater air-ground integration has bolstered confidence that these concepts offer great potential for significant airspace capacity increases in Europe.

A.22 ProATN

A.22.1 Objectives

ProATN (Prototype ATN) is a European project co-funded by the CEC, the Eurocontrol agency and a consortium of 16 partners. The financial set-up of the project is such that most tasks are 50% funded. Some tasks are 100% financed by ProATN partners who, in return for this investment, will retain full rights of ownership to the product developed and thus envisage marketing it commercially. Furthermore, all the hardware and telecommunication costs associated with the test programs are fully covered by Eurocontrol.

The project began in early 1996 and will end in late 2000 (the CEC part has officially ended in December 99). Part 1 of the project consists in defining the requirements, specifying and developing the systems and deploying the network, while Part 2 consists in integrating the ProATN systems in the NLR experimental aircraft and the A340 simulator, performing network validation campaigns, making an analysis of the results of validation and organising the demonstration planned for the 1999 Paris Air Show.

The 16 partners of the ProATN consortium represent all the players on the aeronautical stage: national Civil Aviation administrations and air traffic control agencies, aeronautical firms (aircraft manufacturer, equipment manufacturers), network operators, aeronautical research centre airlines, etc. All the skills required for deployment of a telecommunications network designed to meet the needs of the aeronautical community are thus bought together in this project.

ProATN takes over EURATN and ADS-Europe project, bringing the ATN to the pre-operational level by developing and deploying ATN systems on target operational platforms (Aerospatiale Matra Airbus ATSU and ground Controller Working Positions on the ground).

The main objectives of ProATN are:

- to identify all telecommunication requirements of the future users of the ATN network, so as to define the requirements to be met in terms of network architecture, quality of service, certification and supervision of systems,
- to develop pre-operational ground and airborne systems compliant with the ICAO SARPs standards for CNS/ATM-1,
- to integrate into the ProATN ground and onboard end systems those application services developed under the EOLIA project,
- to deploy all these systems into a European network with 7 ground sites, 1 experimental aircraft (NLR Citation) and one A340 simulator connected by air/ground satellite links (AMSS Data-3), VHF (VDL Mode 2), X25 ground wide area networks and Ethernet local area networks,
- to conduct evaluation campaigns (including several flights of the experimental aircraft and the A340 simulator) co-ordinated with EOLIA Evaluation activities.

A.22.2 Method used

A.22.2.1 ProATN lifecycle

ProATN lifecycle is a generic one. It takes into account the features of the ProATN project, especially the background and the foreground contributions of the partners

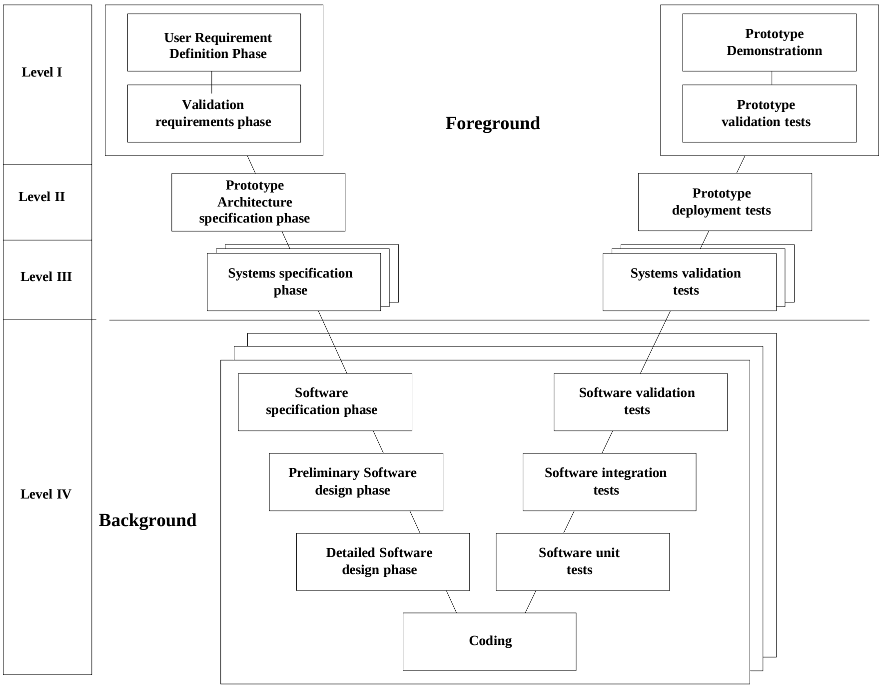


Figure 6: ProATN Life cycle

The project lifecycle has been split into four levels in the "V" cycle. Levels II III and I are foreground activities funded by the CEC and Eurocontrol, whereas level IV (development) is covered by background activities.

A.22.2.2 Co-ordination with the EOLIA project

The ProATN project is very closely linked to another European project called EOLIA. EOLIA is exclusively concerned with the application and operational aspects of CNS/ATM-1. The aim of that project is to develop a set of air/ground application services defined in the frame of CNS/ATM-1 and chosen at the beginning of the project, to integrate them into the ProATN network end systems (ES), to evaluate these services in a quasi-operational environment (in particular involving controllers and pilots), to examine the human factors linked to introducing data link into air traffic control procedures and to conduct a cost/benefit analysis and a safety analysis.

The aims of the ProATN and EOLIA projects are thus clearly separate but nonetheless complementary, with a view to implementation of the CNS/ATM concept. ProATN is a telecommunication project whereas EOLIA is an operational data link evaluation project. The two projects together provide a complete pre-operational CNS/ATM platform in Europe.

The complementary role of the two projects leads them to work closely together so that EOLIA Services can be smoothly integrated into the ProATN systems, with joint evaluation of the CNS/ATM platform. It must be noted that EOLIA and ProATN share a number of common partners: Sofréavia/STNA, Aerospatiale Matra, Airsys-ATM, NATS, NLR, Air France and British Airways.

A.22.3 Main results

A.22.3.1 From the Top-Down phase

A certain number of documents were produced at the beginning of the project during requirement capture and specification phases and can be of general interest externally to the ProATN project.

- **The ProATN User Requirement Document** details the requirements for the ProATN project as identified in the User Forum. These fall broadly into areas: SARPs based requirements and user defined requirements.

- **Network Management Requirements Definition:** The requirements were derived as a result of the ProATN User Forums and also from technical knowledge of network management systems already in use. As the ICAO SARPs do not currently address network management, this activity is seen as providing essential input towards the development of an operational ATN.

- **Certification Requirements Document (CRD):** This report considers the methodologies and standards currently used to approach airborne and ground systems and identifies the requirements that these impose on system development.

- **External Interface Definition document**: this report specifies the interfaces of ESs and BISs that will be externally accessible, such as the ProATN Applications Services Interfaces for the CNS/ATM-1 Package Application Entities that will be developed in ProATN, and the Transport Service Interface.

- **Target performance Requirement Document**: This report tries to set up the performance requirement for an ATN networks operating in an operational environment.

A.22.3.2 From the Bottom-Up phase

Prototype ATN components

ProATN project led to the development of several ATN components amongst which:

1. Ground / Ground, and Air/ Ground Boundary Intermediate System (G/G & A/G BIS) developed by SOF/STNA
2. Ground End System (GES) developed by AATM
3. Ground Network Management Manager (NMS) developed by AATM
4. Airborne Boundary Intermediate System and End System (Airborne ES/BIS) developed and integrated by SXT/AMA.
5. Air/Ground Data Link sub-networks (Satcom, VDL-2)

It is to be noted that ProATN did implement CM, ADS, CPDLC, ASEs except FIS.

The following figure illustrates the ProATN systems deployment.

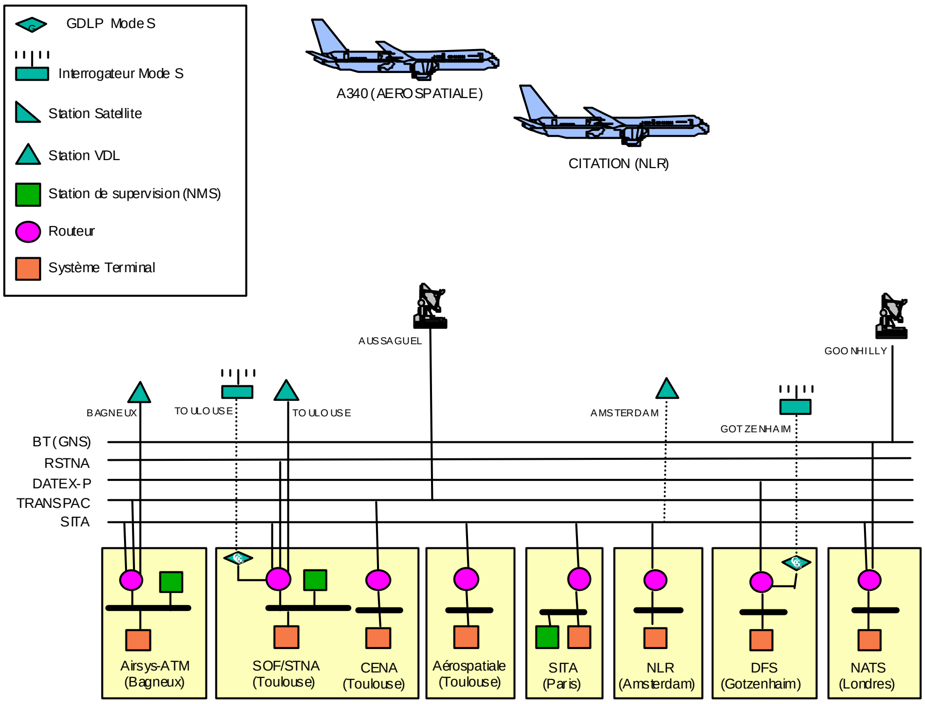


Figure 7 - ProATN sites deployment

A.22.3.3 Le Bourget Demonstration and support of EOLIA validation activities

At the beginning of the ProATN project, it was decided that the Paris Air Show 1999 would be the key event for the demonstration of the ProATN prototype. The Le Bourget was a key event demonstrating the success of both EOLIA/ProATN projects to the public community. During the Airshow, several demonstrations were organised on AATM stand with the NLR Cessna Citation flying over Le Bourget and the AMA A340 Integration simulator. A video link allowed the audience to see what was actually happening in the A340 cockpit as the datalink exchanges were progressing.

Also ProATN supported EOLIA Validation activities which involved several flights from the Cessna Citation with various ground partners (STNA/AATM/NLR/NATS)

EOLIA Controller Working Position
Supporting Data Link services over ATN

A340 cockpit fitted with MCDU, DCDU granting access to ATN based services

All these activities have been supported with Satcom only since VDL-2 is planned to be integrated in August/September 2000 Timeframe.

A.22.3.4 Validation results

Validation activity in ProATN adopted a very straightforward approach. All user requirements having been tagged at the early stages of the project, a validation database and validation plan was set up to cover most of them.

Validation results are detailed in ProATN deliverable D8.3. Going in deep details of the validated User Requirement would be very long, the figure below gives an initial feeling of the validation coverage : 79% of the User requirements have been addressed (which does not necessarily means that ProATN systems fully meet them). The reason for some user requirements not being addressed is mainly related to effort and time constraints during the validation phase. User requirements related to functions that were not implemented are categorised as “tested” but “not fulfilled”

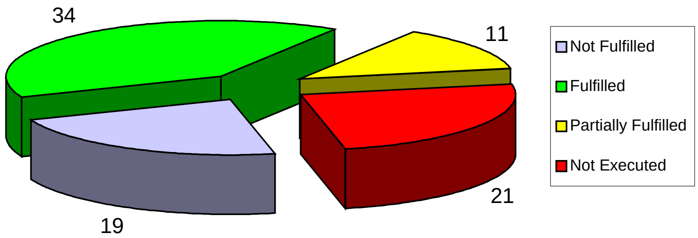


Figure 8 - ProATN validation assessment results

A.22.4 Key Concepts and Requirements Identified

ProATN has enabled an initial international prototype ATN to be deployed, enabling education of the common understanding of the standards (notably the SARPs). The ProATN ground architecture will be used as a basis of the future operational ATN in Europe. It will consequently be a major contributor to the definition and testing of the future European Air Traffic Management Operational Concept. ProATN systems have already been chosen by a number of ATM actors: Eurocontrol in their PETAL II infrastructure, American Federal Aviation Administration (FAA) for the initial phase of the CPDLC programme, M-ADS programme for the surveillance of helicopters in the Norwegian Region.

Expertise gained during ProATN project has allowed a subset of the ProATN industrial partners (Airsys ATM, Sextant Avionique and Sofreavia) together with Honeywell and Allied Signals to create Aeronautical Communication International (ACI) LLC which is yet developing ATN certifiable, portable software (RRI and ASE projects). This software will respond to the airborne certification requirements (which were not covered by ProATN) and will constitute the ATN package for integration into AFAS ATSU.

ProATN development constraints have been under-estimated in ProATN project, which led to delays or reduced functionalities. Experience from ProATN project, for partners which take part in both ProATN and AFAS projects should be used as much as possible to avoid such consequences, since the developing environment are pretty much the same.

The documents identifying requirements (see section A.22.3.1) could be of interest for AFAS/MA-AFAS partners since they are quite generic to the ATN field.

A.23 RHEA

A.23.1 Objectives

There is a real risk that unsuitable automation concepts and systems could be implemented in the future, if automation and/or change of the controller’s tasks were allowed to proceed without a detailed understanding of the optimum allocation of functions and tasks to the human and the automated system.

The RHEA (Role of the Human in the Evolution of ATM Systems) project attempted to reduce these risks, by providing a framework that allows predictions about the chances of success of an automation concept. RHEA was a 140 man-month project, funded by the European commission CEC DGVII, and included 5 European partners, NLR, DERA, SOFREAVIA, THOMSON-CSF and CAA NATS.

A.23.2 Methods Used

WP4 of RHEA provided an extensive list of techniques available for evaluating automation concepts. This list could be used outside RHEA when deciding which evaluation technique to apply when, for example, introducing a new air traffic control procedure. Criteria for choosing techniques are extensively described (e.g. cost of technique, ease of applicability), thereby facilitating the best choice of a technique for the validation case at hand.

The methods of evaluation selected for use within RHEA were:

1. **Queuing network modelling**. This is a model in which a process is described in a graph (a network) in which each node represents a service facility providing a given type of service and a queue for holding entities waiting to be served. This kind of modelling is mainly used in the design of automated systems, to evaluate at an early stage some characteristics of the design, such as performance.
Models were built from available information, using a systems engineering tool (RDD-100), for reference situations and the same situations with the addition of automation concepts, and various indicators computed for various levels of traffic. Thomson-CSF Airsys conducted this evaluation.

2. **Cognitive modelling**. The objective of this activity was to evaluate the situational awareness in the "dynamic aircraft delegation" concept, and more precisely the awareness related to the co-operative work. A model was built, based on heuristic rules determining the information that can be shared for a specific environment and a specific action; A specialised tool (SIM’COOP) has been used. Sofréavia conducted this evaluation activity.

3. **Real-time simulation experiments.** The objective of using this technique was to measure controller's mental workload through physical indicators: pupil diameter, dwell time (the duration of visual fixation), blink rate, blink duration.
It was used during RHEA to evaluate the influence of the use of a descent advisory system on mental workload. This evaluation was conducted by NLR, with the assistance of air traffic controllers.

4. **Fast-time modelling with Petri nets.** Fast time modelling was used to evaluate the impact of the use of STCA tools on controller's workload: the situations were modelled, then each model was evaluated, and resulting workload indicators were obtained. This evaluation activity was also conducted by NLR.

5. **Cognitive walkthroughs** The MACAW (Malvern Cognitive Applied Walkthrough) technique was

adapted for use in RHEA. Its objective is a structured evaluation of automation concepts. It uses large tables to be filled during the evaluation, so that no aspect is forgotten. RHEA evaluations used screen pictures representing tools corresponding to the various concepts. This evaluation was conducted by DERA, with the assistance of experts in the domain and air traffic controllers.

6. **Human Reliability Assessment technique** This technique focuses on the identification of human errors likely to occur for a specific automation concept. It was based on an organised and systematic study of the possible occurrence of several categories of errors, and of their seriousness and likeliness of occurrence in each situation. All automation concepts were evaluated with this technique. This evaluation was conducted by NATS.

A.23.3 Results

The following paragraphs give the benefits and drawbacks for the 9 automation concepts studied within RHEA. A worked example on CINCAT is then given.

Full automation. There is no role for the human in a fully automated system, so it was not studied in detail in the RHEA project. ATM studies, which attempted to build a fully automated ATC system, have all been abandoned (e.g. EUROCONTROL's ARC2000). Whether the reason for lack of success is the unfeasibility of the concept or the lack of expertise to build such a system remains unclear to date.
Benefit: complete predictability of airspace capacity.
Drawback: if system fails, there are no fall-back options.

Controller as supervisor of the system. The controller monitors the system and intervenes in the system dynamics only in exceptional circumstances.
Benefit: unaffected traffic load and allows high productivity and reliability;
Drawbacks: the concept is deemed not suitable because of de-skilling of air traffic controllers (skills necessary if system fails), adverse impact on motivation, poor situation awareness and their related negative impact on safety.

Machine-aided evaluation The system assists in getting the picture, but never makes or even suggests any decision.
Benefit: decrease in controller workload;
Potential drawbacks: superficial situation awareness, possible complacency caused by over-confidence in the output of the tools.

Cognitive tools Machine assistance for organising controller tasks based on typical controller's heuristics.
Benefits: no fundamental change in control principles (core skills are preserved, facilitation of acceptance), decreases memory load, saves human cognitive resources;
Drawbacks: workload overhead when using the tools if they are incompatible with high traffic load, development of selective attention at the expense of monitoring, less global situation awareness, possible complacency by over-confidence in the outputs of the tools.

Machine-proposal strategy The system suggests "solutions" that the controller may choose to implement or not.
Benefits: save human resources, remains indifferent to traffic load, never fails to consider side-effects of actions, overcomes any narrowing of situation awareness or tunnel-vision;
Drawbacks: work overload because of under-confidence in the output of the system, more superficial situation awareness, loss of core skills, loss of flexibility, possible complacency by over-confidence in the output of the system.

Dynamic allocation with machine delegation The system regulates workload by deciding which tasks the controller should perform, and by performing the remaining tasks by itself.
Benefits: capacity gain by work performed by the machine, constant controller workload, core skills are preserved;
Drawbacks: operators are out of control (loss of job satisfaction), risk of poor acceptance, more superficial situation awareness, ambiguity over who is responsible for what at any time, mismatch between system- and controller- behaviour, poor relevance of definition and assessment of workload criteria, impairing of task performance by physiological workload measuring.

Dynamic allocation with human delegation The operator regulates his or her own workload through allocating tasks to the system.
Benefits: capacity gain by work performed by the machine, the controller is still much in control, core skills are preserved since the controller keeps a performing role;
Drawbacks: ambiguity over who is responsible for what at any time, additional workload from manipulation and monitoring of the system, loss of job satisfaction when tasks are delegated.

Dynamic aircraft delegation The operator delegates some control tasks to the pilot.
Benefits: possible optimisation of control actions when performed airborne, reduced controller workload, core skills are preserved since the controller keeps a performing role, shared context is increased through explicit co-ordination;
Drawbacks: the behaviour of the aircraft can be unpredictable (loss of anticipation and situation awareness), additional workload from co-ordination with pilots and monitoring of aircraft behaviour, loss of job satisfaction when tasks are delegated, ambiguity over who is responsible for what at any time, increased pilot workload.

HMI enhancement A good Human Machine Interface is essential for each automation concept. An automation concept may be very well thought through on a conceptual level and even be implemented successfully from a system's point of view, if the HMI has not been considered sufficiently, there is a big chance of failure of the automation concept.
As a worked example, the project CINCAT was rated on each of the 9 automation concepts. This analysis showed that the CINCAT project is not based on one particular automation concept. As a consequence there is a risk of confounding advantages and problems of the different automation concepts. This highlights the fact that before the CINCAT project started, no thorough explicit automation conceptualisation was carried out.
As the worked example indicates, analysing an automation concept before implementing it, could prevent the occurrence of predictable drawbacks, usually associated with the automation concept under study.

A.23.4 Requirements

The RHEA project gave 46 requirements for automation in ATM systems, under the following headings.

Requirements about specific automation tool issues

- Requirements about comprehensibility of tools
- Requirements about flexibility of tools
- Requirements about distinctness of tools
- Requirements about communication between a tool and the controller
- Requirements about communication (multi-tool issues)
- Requirements about tools reliability

Requirements depending on automated tasks

- Communication between humans
- Communication between humans and machine
- Negotiation
- Monitoring
- Planning
- Decision-making

Requirements depending on the level of automation

- No automation
- Only digitisation
- Data processing for improvement in accuracy
- Assistance
- Automated task sharing between controller and machine
- Supervision of human work
- Complete automation, with human supervision
- Complete automation, without human supervision

A.24 RTCA SC-186 Activities

A.24.1 Introduction

The Special Committee 186 (SC-186), entitled “Automatic Dependent Surveillance – Broadcast” was established in February 1995.

The Chairmen are from the Federal Aviation Administration and United Airlines.

The committee is tasked to develop operational requirements and minimum performance standards for ADS-B. The committee will consider both airborne and ground user needs for this capability.

Four Working Groups are active:

- WG1 - Operations and Implementation,
- WG2 - Separation Assurance,
- WG3 - 1090 MHz MOPS for ADS-B,
- WG4 - Application Technical Requirements.

A.24.2 Objectives

The main objectives of Special Committee 186 were to:

- develop the operational requirements based upon the airborne and ground user needs for an Automatic Dependent Surveillance-Broadcast (ADS-B) system;
- prepare the consequent Minimum Aviation System Performance Standards (MASPS) for ADS-B;
- develop a list of proposed applications for the use of ADS-B information in the aircraft and on the ground, describing the operational concept for each application in sufficient detail to ensure a common understanding of the concept, and develop appropriate definitions of Required Monitoring Performance (RMP);
- develop Minimum Operational Performance Standards (MOPS) for an ADS-B system operating on 1090 MHz frequency;
- develop MOPS for a Cockpit Display of Traffic Information (CDTI), taking into account the work already done for the Traffic alert and Collision Avoidance System (TCAS) traffic display.

A.24.3 Main results

A.24.3.1 RTCA/DO-242 - Minimum Aviation System Performance Standards for ADS-B

This document, issued 19 February 1998, provides a view of the system-wide operational use of Automatic Dependent Surveillance - Broadcast. ADS-B is a function of an aircraft or surface vehicle that periodically broadcasts its state vector and other information.

Section 1 “*Purpose and Scope*” describes the ADS-B system and provides information needed to understand the rationale for system characteristics and requirements. It describes typical applications and operational goals.

Section 2 "*Operational Requirements*" describes operational performance requirements for a candidate set of potential ADS-B applications. It provides specific scenarios for more detailed analysis based on the applications introduced.

Section 3 "*ADS-B System Definition and Functional Requirements*" defines system level performance requirements, defines subsystems and allocates these requirements to subsystems. Interfaces and equipage classes are defined as well as specific ADS-B requirements.

Section 4 "*Procedure for Requirement Verification*" describes minimum system test procedures.

It also includes 13 appendixes, with in particular Appendix D "*Near-Term Applications for Initial ADS-B Implementation*" which provides 23 near-term cockpit applications and 14 potential near-term ATS surveillance applications and Appendix E "*Other Applications*" which provides 37 other applications that may be supported by ADS-B.

A.24.3.2 RTCA/DO-243 – Guidance for Initial Implementation of CDTI

This document, issued 19 February 1998, provides guidelines in the design and development of an initial set of CDTI features. CDTI is the function of presenting surveillance information about the surrounding traffic to the flight crew.

This guidance document is advisory in nature and its contents are expected to be a subset of the final CDTI MOPS. These MOPS, when published, will replace this document. In order to comply with certification standards, manufacturers will be required to demonstrate that:

1) CDTI meets its intended functions, and
2) CDTI does not interfere with any other aircraft systems.

This interim guidance provides a description of the intended functions of CDTI and as such may aid the certification process.

A.24.3.3 RTCA/DO-249 – Development and Implementation Planning Guide for ADS-B Applications

This planning Guide, issued 6 October 1999, outlines suggested activities for the development and implementation of ADS-B applications. It documents the range of activities that need to be in place to bring an application from an initial concept to operational use. These activities are of two types.

- Development Activities:
  1. Operational Concept
  2. Benefits and Constraints
  3. Maturity of Concept and Technology
  4. Operational Procedures
  5. Human Factors Issues (Pilot, Controller, Other)
  6. End-to-End Performance and Algorithm Requirements (Minimum and Desirable)
  7. Interoperability Requirements for Airborne and Ground Systems
  8. Operational Safety Assessment
  9. Operational Test and Evaluation

- Implementation Activities
  10. Equipment Certification (Aircraft and Ground Systems)
  11. Operational Approval (Flight Standards and Air Traffic)
  12. Implementation Transition

It provides an example for the Cargo Airline Association "Enhanced Visual Acquisition" ADS-B Application. In addition, the Closely Spaced Parallel Approaches Sub-Group of WG1 is developing a document "*Operational Concept for Closely Spaced Parallel Approaches*" using this planning Guide.

A.24.4 Current activities

A.24.4.1 1090 MHz Minimum Operational Performance Standards for ADS-B

1090 MHz MOPS for ADS-B is targeted for completion in June2000. This is a joint document with EUROCAE.

A.24.4.2 Operational Concept for CDTI Initial Applications

The Draft 7.0 of the document (RTCA Paper No. 186-98/SC186-128) was reviewed and approved at the Plenary Meeting in March 2000.

This document contains operational concepts for CDTI initial applications. It:

- provides a preliminary description of four potential procedures utilising a CDTI that may enhance current air traffic operations:
  - ✓ Enhanced Visual Acquisition
  - ✓ Enhanced Visual Approach
  - ✓ In-Trail (or lead) Climb and Descent in Non-Radar Airspace (Oceanic, En Route, and Remote
  - ✓ In-Trail (or lead) Climb and Descent to Co-Altitude in Non-Radar Airspace (Oceanic, En Route, and Remote)
- describes the underlying pilot and controller tasks and responsibilities; and
- derives required CDTI capabilities to enable the pilot to perform these tasks.

The intent of this document is to develop an initial definition of the procedures with sufficient detail to allow a specification of required CDTI capabilities, so that when the procedures are fully developed, tested and evaluated, and certified for use, the equipment may be capable of facilitating the implementation.

This document is accompanied by a companion document titled, "*Minimum Operational Performance Standards for Cockpit Display of Traffic Information Version 1.0*" which specifies the minimum performance standards for the control and display elements for each of the applications described in this document. The MOPS for CDTI requirements are not only applicable to the four applications described in this document, they are intended to support other applications that are not yet fully developed but are possible if the requirements are met. Finally, a third companion document titled, "*Minimum Operational Performance Standards for Airborne Surveillance and Separation Assurance Processing (ASSAP)*" will specify associated airborne system performance requirements.

A.24.4.3 Minimum Operational Performance Standards for CDTI

(based on CDTI MOPS Draft 25L – September 1999)

The document is scheduled for review at the Plenary Meeting in June 2000 and completion in September 2000.

The scope of this document is to specify MOPS for the flight crew interface for the cockpit display of traffic information, which includes the traffic display and all the controls that interact with such a display. This document specifies a set of the very minimum control and display elements and their performance standards for traffic situational awareness. Additional minimum performance standards for control and display elements are specified based on other aircraft operational applications to be performed using the information. The requirements in this document apply to all hardware and software that perform the CDTI function.

Section 1.0 "*Purpose and scope*" provides information and assumptions needed to understand the rationale for equipment characteristics and requirement stated in the remaining sections. It describes typical applications and operational goals and establishes the basis for the standards stated in Sections 2 through Section 3. Definitions and assumptions essential to proper understanding of this document are also provided in this section.

Section 2.0 "*Equipment performance requirements and test procedures*" contains the minimum performance standards for the equipment. These standards specify the required performance under standard operating and environmental conditions. CDTI capabilities and associated performance requirements are provided. Also included are recommended bench test procedures necessary to demonstrate equipment compliance with the stated minimum requirements.

Section 3.0 "*Installed equipment performance*" describes the performance required of the installed equipment. Tests for the installed equipment are included when performance cannot be adequately determined through bench testing.

Section 4.0 "*Equipment operational performance characteristics*" describes the operational performance characteristics for equipment installations and defines conditions that will assure the equipment user that operations can be conducted safely and reliably in the expected operational environment.

This document accompanies the document "*Operational Concept for CDTI Initial Applications*".

A.24.4.4 Minimum Operational Performance Standards for ASSAP

(based on ASSAP MOPS Draft 0.6 – March 2000)

The MOPS for "Airborne Surveillance and Separation Assurance Processing" is planned for Plenary review in September 2000 and completion December 2000.

ASSAP refers to aircraft-based functionality that provides aircraft with airborne separation assurance capabilities. Some examples of planned ASSAP applications are provided: the four applications described in the document "*Operational Concept for CDTI Initial Applications*", conflict detection and resolution (CD&R), and parallel approaches to closely spaced runways.

ASSAP performs three main functions:

- Surveillance processing of available surveillance inputs (e.g., from ADS-B, TIS-B, TCAS, etc.) to develop surveillance traffic reports and tracks, which are output to the CDTI function for display to the flight crew as well as to the Separation Assurance functions. It consists of correlation, data fusion, data integrity monitoring, registration error estimation, and actual surveillance performance (ASP) determination.
- Conflict detection and resolution (CD&R) processing to provide separation assurance from other traffic by predicting conflicts within a region of interest to the flight crew consistent with the current operation and if a conflict is detected, by calculating and presenting resolutions to the flight crew for a response.

- Cooperative separation maintenance processing, which provides the flight crew with separation assurance automation support and alerting in flight operations requiring establishment and maintenance of separation with a specifically identified aircraft.

A core objective of the ASSAP MOPS is to specify Required Surveillance Performance (RSP) needed to support aircraft-based surveillance and separation assurance applications, and to specify functional testing that assures RSP requirements are correctly implemented.

The document addresses the relationship between ASSAP and ACAS/TCAS. Any possible relationship and interdependence between ASSAP and ACAS/TCAS must be carefully investigated in safety analyses and hazard assessment studies to assure that overall system safety is achieved. Some discussions on this issue are going on between RTCA and ICAO/SICASP.

The development of the MOPS is under process and the draft version is evolving very often.

A.24.4.5 Concept of Operations for aircraft based traffic conflict detection and resolution

(based on CD&R ConOps Version 2.7telcon – 30 March 2000)

This document presents a Concept of Operations (ConOps) for airborne Conflict Detection and Resolution (CD&R) using ADS-B.

The CD&R concept includes detecting conflicts as well as providing resolutions that prevent violation of airspace separation criteria against other properly equipped vehicles.
CD&R includes three different functions:

- Conflict Detection, which provides an automated alerting aid to the pilot to help detect existing conflicts with other aircraft. The actions in response to this alert may either be coordinated with the air traffic service provider or solely managed by the pilot, depending on the operating environment and flight rules in effect at the time of the encounter.
- Conflict Resolution, which provides recommended conflict resolutions or guidance cues. This function is designed to be completely interoperable with and functionally independent of ACAS.
- Conflict Prevention, which predicts conflicts that may occur if current flight parameters are changed. As such, it will offer guidance cues to prevent changes that will lead to conflicts.

Section one “*Purpose and Scope*” contains background, operational purpose and justification, intended airspace domains, and maturity and user interest.

Section two “*CD&R Overview*” covers the heart of the concept to include conflict zones, conflict detection, conflict resolution, airspace operations, and pilot/controller responsibilities.

Section three “*CD&R - ACAS/ADS-B Interoperability*” addresses the issue of relationship between CD&R and ACAS. However, both equipment have different purposes: CD&R aims at assuring separation between aircraft and ACAS at preventing collisions.

Section four “*Equipage in a Free Flight Environment*” describes the various equipage levels expected, and their operational use.

A.24.5 ATM key concepts and requirements identified

Three important documents are available:

- RTCA/DO-242 - Minimum Aviation System Performance Standards for ADS-B
- RTCA/DO-243 – Guidance for Initial Implementation of CDTI
- RTCA/DO-249 – Development and Implementation Planning Guide for ADS-B Applications

In addition, four other ones are under development and should be completed by the end of 2000:

- Operational Concept for CDTI Initial Applications
- Minimum Operational Performance Standards for CDTI
- Minimum Operational Performance Standards for ASSAP
- Concept of Operations for aircraft based traffic conflict detection and resolution

They provide relevant information related to the ASAS/CDTI theme for the definition of operational concept, the identification of functionalities and the identification of issues in the design of the avionics package.

A.25 Safe Flight 21 (FAA)

A.25.1 Outline

Safe Flight 21 is a co-operative government/industry effort to evaluate enhanced capabilities, and expedite decisions, for Free Flight based on evolving Communications, Navigation and Surveillance (CNS) technologies. Safe Flight 21 will demonstrate the in-cockpit display of traffic, weather and terrain information for pilots and will provide improved information for controllers. The new technologies on which this program is based include the Global Positioning System (GPS), ADS-B, Flight Information Services (FIS), Traffic Information Service – Broadcast (TIS-B), and their integration with enhanced pilot and controller information displays. Safe Flight 21 will evaluate the safety, service and procedure improvements these technologies make possible.

Safe Flight 21 plans to incrementally specify, develop and evaluate the operational enhancements called for in the RTCA Select Committee, Joint Government/Industry Roadmap for Free Flight Operational Enhancements, (FFEOP), August, 1998. This document defines nine CNS-based operational enhancements at a high level, identifies types of potential benefits, gives examples of risks and issues to be resolved, and specifies the emphasis and locations where these enhancements will be evaluated. It also identifies additional benefits and synergies that are expected if multiple capabilities are implemented together.

Under the auspices of the FAA's Safe Flight 21 office there are two major ADS-B demonstration projects in the United States. The Ohio Valley demonstration is evaluating ADS-B equipment and procedures in large transport category jets operating at hub airports in the Midwest. The Alaska Capstone program is demonstrating ADS-B applications in smaller general aviation aircraft operating in a region of Alaska. Technology used in both demonstration programs is compatible. Table 1 shows how the two operational demonstrations will show the nine enhancements.

Operational Enhancement	**Ohio Valley**	**Alaska**
1 Weather and Other Information to the Cockpit	**N**	**Y**
2 Cost Effective CFIT Avoidance	**N**	**Y**
3 Improved Terminal Operations in Low Visibility	**Y**	**N**
4 Enhanced See and Avoid	**Y**	**Y**
5 Enhanced En Route Air-to-Air Operations	**Y**	**Y**
6 Improved Surface Surveillance & Navigation for the Pilot	**Y**	**Y**
7 Enhanced Surface Surveillance for the Controller	**Y**	**Y**
8 ADS-B Surveillance in Non-Radar Airspace	**N**	**Y**
9 ADS-B Surveillance in Radar Airspace	**N**	**Y**

Table 3: Operational Enhancements to be Performed by Demonstrations

A first step toward developing and evaluating these nine high-level enhancements is to clarify the specifics of what they include and develop top-level details of the operations involved and the systems required. The Safe Flight 21 Steering Group has taken this step and defined the scope of Safe Flight 21 in terms of specific applications (within the enhancements) that will be developed and evaluated. These applications are described in more detail in Annex A: Safe Flight 21 Enhancements and Applications.

A.25.2 Objectives

Safe Flight 21 aims to gain a consensus on the feasibility of these enhancements, prepare a business case and expedite decisions concerning them.

Certification and obtaining operational approval from the FAA represent significant risks to achieving these enhancements. Therefore, the program will have an objective to develop innovative processes to expedite the certification and operational approval of these enhancements when they are shown to be both feasible and useful to the stakeholders.

A.25.3 Key Concepts and Requirements identified in this project

The Safe Flight 21 Program can be seen to be similar to MA-AFAS, with some technologies already selected and trials conducted. Table 1 shows the technologies/concepts that are considered to bring the most benefit in the shortest time scale, and therefore will be investigated and operationally demonstrated.

The Master Plan for Safe Flight 21 also includes results of studies into the effect of partial equipage, particularly with respect to the possible applications.

One sub group, the Link Evaluation Team (LET), aims to evaluate the three contenders for the ADS-B data link to enable a choice to be made. The LET is investigating a number of aspects of link implementation, including spectrum allocation, compliance to MASPS, standards development, and multipath mitigation. As of November 1999, only preliminary results are available. It appears that the US would wish VDL Mode 4 to occupy a different frequency range to that used in Europe. VDL Mode 4 is expected to have the best multipath mitigation, but it does not comply to the MASPS state vector update requirements.

Improved weather information systems is also expected to bring important operational benefits.

A.25.4 References

1. Safe Flight 21 Master Plan, Version 2, Safe Flight 21 Steering Group, April 2000.
2. Phase One Link Evaluation Report, Status and Initial Findings, ADS-B Link Evaluation Team, November 1999.

A.25.5 Annex : Safe Flight 21 Enhancements and Applications

Enhancement		OpEval Fiscal Year	Application
Weather and Other Information to the Cockpit	1.1.1	00 (AK)	Initial FIS-B based on today's availability (NEXRAD graphics, METAR/SPECI, TAFs, SIGMETs, PIREPs and severe weather forecast alerts)
	1.1.2	01 (AK)	Add products such as NOTAMs, lightning, icing, turbulence, real time SUA, and Volcanic ash
Cost Effective CFIT Avoidance	2.1	00 (AK)	Low cost terrain situational awareness
	2.2	01 (AK)	Increased access to terrain constrained low altitude airspace
Improved Terminal Operations in Low Visibility	3.1.1	99 (ORV)	Enhanced visual approaches (Visual acquisition with existing procedures, ADS-B only)
	3.1.2	00 (ORV)	Enhanced visual approaches (with new procedures using ADS-B only)
	3.1.3	01 (ORV)	Enhanced visual approaches (with new procedures using ADS-B and TIS-B)
	3.2.1	00 (ORV)	Approach spacing (for visual approaches)

	3.2.2	01 (ORV)	Approach spacing (for instrument approaches)
	*3.3		Enhanced parallel approaches in VMC/MVMC
	3.4	00 (ORV)	Departure spacing/clearance (VMC in radar)
	*3.5		Approaches to closely space parallel runways
Enhanced See and Avoid	4.1.1	99 (ORV)	Enhanced visual acquisition of other traffic for see-and-avoid (using ADS-B only)
	4.1.2	01 (Both)	Enhanced visual acquisition of other traffic for see-and-avoid (ADS-B and TIS-B)
	4.2.1	00 (ORV)	Conflict detection
	4.2.2	02 (ORV)	Conflict resolution
Enhanced En Route Air-to-Air Operations	*5.1		Closer climb and descent in non-radar airspace
	5.2.1	00 (AK)	Pilot situational awareness beyond visual range
	*5.2.2		Delegated air-to-air self-separation for one-in-one-out airspace
	*5.3		In-trail spacing in en route airspace
	*5.4		Merging in en route airspace
	*5.5		Passing manoeuvres in en route airspace
Improved Surface Surveillance and Navigation for the Pilot	6.1.1	00 (Both)	Runway and final approach occupancy awareness (using ADS-B only)
	6.1.2	01 (ORV)	Runway and final approach occupancy awareness (using ADS-B and TIS-B)
	6.2	01 (Both)	Airport surface situational awareness
	*6.3		Enhanced IMC airport surface operations
Enhanced Surface Surveillance for Controller	7.1	00 (ORV)	Enhance existing surface surveillance with ADS-B
	7.2	01 (ORV)	Surveillance coverage at airports without existing surface surveillance
Surveillance in Non-Radar Airspace	8.1	00 (AK)	Center situational awareness with ADS-B
	8.2	00 (AK)	Radar-like services with ADS-B ADS-B
	8.3	00 (AK)	Tower situational awareness beyond visual range
Establish ADS-B Separation Standards	9.1.1	00 (Both)	Radar augmentation with ADS-B to support mixed equipage in terminal airspace
	*9.1.2		*9.1.2 Radar augmentation with ADS-B to achieve existing separation standards in terminal airspace
	9.2.1	00 (Both)	9.2.1 00 (Both) Radar augmentation with ADS-B to support mixed equipage in en route airspace
	*9.2.2		*9.2.2 Radar augmentation with ADS-B to achieve existing separation standards in en route airspace
	*9.3		Reduced separation standards with ADS-B

*Applications that will not be evaluated between 1999 and 2002

The RTCA Select Committee was very explicit, at a high level, in their FFEOP document concerning the scope of evaluations that they expected in order to advance the modernisation of CNS in the NAS. The Safe Flight 21 Steering Group, comprising the stakeholders interested in these enhancements, have come to a consensus on the applications that will be initially developed and evaluated to show the benefits and reduce the risk of implementing the enhancements.

This section reiterates the nine enhancements from the Roadmap and breaks out the applications that will be evaluated. Since this is an evolving plan, a mapping to applications that have been considered in previous versions of this plan is made at the end of the section. There are applications similar to these defined, or at least alluded to, in the ADS-B MASPS, the ATS Concept of Operations for the National Airspace System in 2005, and the Government/Industry Operational Concept for the Evolution of Free Flight. The mapping at the end of this section shows those connections. The applications currently planned for evaluation by Safe Flight 21 are summarised below. The application descriptions that follow include all phases within the applications.

Enh. 1: Weather and Other Information to the Cockpit

This enhancement will use the Flight Information System (FIS) to receive current and forecasted weather and flight information as well as other information. The enhanced weather products will be available to pilots and controllers, allowing them to share the same situational awareness. The information will be displayed textually and graphically to the pilot.. The expected benefits are the following:

- Reduced flight times by skirting adverse weather
- Reduced flight times by exploiting available SUA
- Increased safety
- Reduced Flight Service Station workload
- More GA flight initiatives with weather information during flight
- Improvement in tactical planning for aircraft equipped with weather radar
- Improvement in tactical planning for aircraft equipped with icing and SUA graphics

App. 1.1.1 Initial FIS-B
This application will enhance pilot awareness of weather and airspace/facility status by incorporating broadcast flight information into cockpit multifunction displays. Initial (text only) products will include NEXRAD graphics, METAR and SPECI surface observations, TAFs and applicable amendments, SIGMETs and convective SIGMETs, AIRMETs, urgent and routine PIREPs, and Severe Weather Forecast Alerts.

App. 1.1.2 Additional FIS-B Products
This application will add additional exchange of aeronautical data that includes NOTAMs, lightning, icing, turbulence, real-time SUA, and volcanic ash.

Enh. 2: Cost Effective CFIT Avoidance

There have been many fatal accidents involving controlled flight into terrain (CFIT) due to poor pilot situational awareness. This enhancement will increase the pilot’s situational awareness by providing a cost/effective terrain and obstacle database and integrated display in the cockpit. The expected benefits are the following:

- Reduced CFIT accidents
- Decreased pilot workload
- Increased access to low altitude routes
- Increased capability to avoid hazardous weather conditions relating to certain altitude (e.g., icing)
- Increased ability to fly at lower altitude to avoid need for IFR at higher altitude

App. 2.1 Low cost terrain situational awareness
This application will enhance pilot awareness of terrain by using on-board databases, GPS navigation, and barometric altitude to generate moving terrain maps on cockpit multifunction displays. The initial capability colour-codes vertical clearance to terrain, suitable for VFR operation.

App. 2.2 Increased access to terrain constrained low altitude airspace
This application adds capabilities including obstacle data to the on-board databases and provides alert functions. This increased situational awareness may facilitate lower altitude GPS routes or lower altitude random off-airway navigation for suitably equipped aircraft.

Enh. 3: Improved Terminal Operations in Low Visibility

This enhancement will use ADS-B, CDTI and TIS-B during low visibility approach operations so that the crew will be better able to identify the aircraft to follow and accomplish approaches at lower minimums, thus maintaining VFR throughput longer. The crew will also be able to maintain better spacing during VFR and IFR approaches. The expected benefits are the following:

- Increased access to airports during marginal weather
- Reduced arrival delays
- Increased predictability of arrival & departure times
- Increased flexibility of arrival scheduling
- Increased airport capacity
- Increased safety for terminal area approaches and departures
- Increased efficiency of terminal operations
- Reduced go-arounds
- Enhance special VFR airspace access
- Decreased controller workload
- Decreased voice communications and increased voice-channel availability

App. 3.1 Enhanced visual approaches

This application helps pilots visually acquire and identify the aircraft called-out by controllers prior to visual approach clearances by showing the identity and trajectory of aircraft on a CDTI. By using the CDTI to aid in the transition to a visual approach, the procedure will be used more often and more efficiently. Visual approaches are the backbone of operations at major airports in the US and provide greater arrival capacity than IFR operations. During visual approaches, traffic advisories are issued to pilots, and once the pilot confirms acquisition of traffic and runway, a visual approach clearance is issued. Most facilities have specific established minima to which visual approaches can be conducted; however, specific environmental conditions such as haze, sun light, and patchy clouds may result in the suspension of visual approaches at higher ceiling and visibility values. CDTI may help enhance visual approach operations in one of several ways including:

- Improved visual traffic acquisition
- Reduction in pilot and controller workload
- Increased reliability of conducting visual operations to established minima
- Reduction in the minima to which visual approaches are conducted

The first phase (3.1.1) of the application avoids significant changes to air traffic management (ATM) communication procedures by not including flight ID in traffic call-outs by controllers. This phase also avoids requiring any additional functionality in the ground automation systems by relying solely on the ADS-B of equipped aircraft for the information displayed on the CDTI.

The second phase (3.1.2) of the application extends current pilot/controller procedures for visual approaches to take explicit advantage of the positive identification of traffic that is supported by ADS-B/CDTI. The procedures for traffic call-out by the controller to a CDTI equipped aircraft will be changed to include the flight ID of the traffic. This is expected to further enhance the safety and efficiency of visual approaches.

In the third phase (3.1.3) of the application, non-equipped aircraft appear on the CDTI based on a Traffic Information Service Broadcast (TIS-B) of ground radar-based data. This makes the application more broadly usable in situations of mixed equipage. This phase of the application will address the TIS-B function in the ground automation systems and the human factors issues of presenting TIS-B targets on the CDTI.

App. 3.2 Approach spacing

This application will provide the pilot with additional cues on the CDTI regarding the dynamics of the aircraft that the pilot is following to improve safety and efficiency.

The first phase (3.2.1) of this application will additional cues on the on visual approach and guidance toward achieving a desired interval. These cues and guidance are expected to allow the pilot to make more consistent and efficient visual approaches.

The second phase (3.2.2) of this application will apply these tools (with extension if needed) for instrument approaches. Spacing near minimum radar separation standards will provide more consistent arrival intervals and higher arrival rates. The pilot will receive radar vectors from ATC to intercept the approach course, and at an appropriate time will be given a spacing interval behind the preceding arrival. At a later time, further enhancements to the CDTI may aid in optimising protection from wake vortex induced by the lead aircraft.

App. 3.4 Departure spacing/clearance
Often minimum spacing is not obtained on departure because of controller workload, pilot response time, and/or limitations of radar surveillance. However, if the CDTI function can aid pilots in departing and maintaining spacing behind a leading aircraft, the controller may be able clear the aircraft for departure based on CDTI spacing and gain additional throughput over the departure routes.

Enh. 4: Enhanced See and Avoid

This enhancement will provide traffic information, electronically, to the cockpit using ADS-B, CDTI, and TIS-B. This will enable the pilot to maintain situational awareness of surrounding traffic. The expected benefits are the following:

- Increased safety
- Decrease in pilot/controller workload
- Resolve conflicts earlier with resulting efficiencies
- Reduce disruptions to ATC
- Increased capacity
- Increased efficiencies
- Change in tower establishment criteria

App. 4.1 Enhanced visual acquisition of other traffic for see-and-avoid
This application provides a display of nearby traffic on the CDTI to help the pilot see-and-avoid traffic. If traffic is sighted, the pilot must first assess the threat posed by the nearby aircraft then, if necessary, manoeuvre to avoid the other aircraft. The effectiveness of see-and-avoid depends on the ability of a pilot to visually acquire the nearby aircraft early enough in the encounter to enable threat assessment and avoidance.

The first phase (4.1.1) of this application will be to evaluate see-and-avoid using only ADS-B/CDTI. This will show nearby aircraft that are equipped with ADS-B.

The second phase (4.1.2) of this application extends the CDTI by displaying non-equipped aircraft which are detected by ATC radar and transmitted to the CDTI using TIS-B. In areas with significant numbers of aircraft that are not ADS-B equipped, the effectiveness of using CDTI based on ADS-B only for acquisition of traffic would be limited. With TIS-B information, the identity, position and estimated ground speed of the other traffic that are known to the controller will be supplied to the pilot. This will assist equipped pilots by providing a display of all nearby traffic within the TIS-B supported area. This phase of the application will address the TIS-B function in the ground automation systems and the human-factors issues of presenting TIS-B targets on the CDTI.

App. 4.2.1 Conflict Detection
This application alerts pilots to potential conflicts with other aircraft, thereby facilitating timely action (if necessary) to prevent or end the conflict This application will address human factors and algorithm issues such as false alerts, the relationship to TCAS alerts, and indirect impacts on ATC operations.

App. 4.2.2 Conflict Resolution
This application advises the pilot of a manoeuvre to resolve the previously detected conflict. This application will address human factors and algorithm issues and will address potential interactions with TCAS on one or both aircraft.

Enh. 5: Enhanced En Route Air-to-Air Operations

This enhancement will evaluate use of CDTI and ADS-B to allow delegation of separation authority to the cockpit, resulting in increased efficiency. The expected benefits are the following:

- Increased en route capacity
- Increased fuel efficiency
- Increased pilot flexibility
- Decreased controller workload
- Increased throughput for “one-in/one-out” airspace

App. 5.2.1 Pilot situational awareness beyond visual range
This application extends pilot situational awareness of traffic that is beyond visual range by including distant traffic and airspace boundaries on the cockpit multi-function display. The application is intended to aid pilot-pilot co-ordination in VFR, SVFR and night operations by showing the overall multiple-aircraft pattern of operations in the airspace rather than only those aircraft that are closest and within visual range. Air-to-air ADS-B messages will identify and give the trajectory of ADS-B equipped aircraft. Ground-to-air TIS-B messages will identify and give the trajectory of non-equipped aircraft that are in radar surveillance.

Airspace boundaries will be presented from an on-board database.

Enh. 6: Improved Surface Surveillance and Navigation for the Pilot

This enhancement will be designed to allow pilots in the cockpit and the operators of equipped vehicles on the airport surface to “see” all the other traffic on a display with a moving map, resulting in safer and more efficient surface operations. Also, aircraft will be able to taxi using augmented GPS navigation and maps and in extremely low visibility conditions using LAAS. The expected benefits are the following:

- Increased safety during surface movements
- Increased safety during approaches, landings and take-offs
- Reduced taxi times
- Increased predictability of taxi times
- Increased airport capacity (aircraft operations)
- Improved efficiency of gate management operations
- Improved surface operations (all surface operations)
- Improved airport surface operation in IMC conditions
- Reduced surface controller workload

App. 6.1 Runway and final approach occupancy awareness
This application provides pilots on final approach and on the runway with awareness of other aircraft that are on or approaching the runway.

The initial phase (6.1.1) of this application provides awareness only of equipped aircraft and/or vehicles, and will be of benefit primarily in situations where all or nearly all aircraft/vehicles are equipped. Evaluation will initially be based on the capabilities of un-augmented GPS and basic CDTI, but augmented GPS or limited CDTI enhancements may be found necessary.

The second phase (6.1.2) increases the value of the application by including non-ADS-B-equipped aircraft on the CDTI. The ADS-B data on the CDTI is augmented with TIS-B data from ground-based terminal and surface radar and multilateration techniques. This will provide the pilot of equipped aircraft with information on equipped and non-equipped aircraft, vehicles, and obstructions.

App. 6.2 Airport surface situational awareness
This application enhances the pilot's visual situational awareness by displaying an airport map with aircraft, vehicle, and obstacle positions based on ADS-B (and possibly TIS-B). GPS augmentation with WAAS is expected to be necessary (and adequate) for this application.

Enh. 7: Enhanced Airport Surface Surveillance for the Controller

This enhancement will equip the aircraft and ground vehicles in the airport movement area with ADS-B using augmented GPS-derived positions. The local and ground controllers in the tower will monitor the position and speeds of all the traffic in the movement area. The expected benefits are the following:

- Increased safety during surface movements
- Increased safety during landings and take-offs
- Reduced taxi times
- Increased predictability of taxi times
- Increased airport capacity (aircraft operations)
- Improved efficiency of gate management operations
- Reduction in emergency response time
- Improved surface operations (all surface operations)
- Reduced rate of pilot/air traffic control communications

App. 7.1 Enhance existing surface surveillance with ADS-B
This application integrates the position, identification, and speed of all equipped ADS-B aircraft with existing surface surveillance to fill the gaps in the existing coverage. The local and ground controllers in the tower could then monitor the position and speeds of all the equipped aircraft.

App. 7.2 Surveillance coverage at airports without existing surface surveillance
This application uses ADS-B and multi-lateration of other radar returns to provide surface surveillance capabilities at airports without existing surface surveillance. This would increase safety monitoring, enhance crash, fire, and rescue capabilities, as well as improve ground ATC operations.

Enh. 8: ADS-B for Surveillance in Non-Radar Airspace

This enhancement will use ADS-B to provide additional surveillance coverage and fill gaps in today's radar coverage. The expected benefits are the following:

- Increased capacity in airports and airspace
- Reduced separation minima in comparison to procedural separation
- Increased flexibility in route flown
- Increased safety
- Increased efficiency in aircraft operations
- Increased predictability of flight times
- Reduced flight delays

App. 8.1 Centre situational awareness with ADS-B
This application provides centre controllers with enhanced situational awareness of traffic in non-radar airspace by identifying ADS-B equipped aircraft and their trajectories on a controller display. This will aid the controller in providing procedural separation and other non-radar services and in co-ordinating with the tower controller on airspace changeovers between IFR en route operations and terminal area SVFR operations. Potential uses of ADS-B to aid search and rescue and for communicating aircraft emergency conditions to the controller are being considered for inclusion in this application.

App. 8.2 Radar-like services with ADS-B
This application provides terminal area controllers of non-radar airspace with surveillance, conflict alert and MSAW that are based on ADS-B, to enable provision of radar-like services to VFR and IFR aircraft. This includes emergency services, separation, sequencing, traffic and terrain advisories, navigational assistance, and route optimisation. Aircraft not providing ADS-B are handled similarly to aircraft without a transponder in secondary radar airspace.

App. 8.3 Tower situational awareness beyond visual range
This application extends the tower cab controller situational awareness of traffic that is beyond visual range by using ADS-B to identify aircraft and their trajectories on a tower display. This application is intended for VFR, SVFR and night operations and will aid tower-pilot and tower-centre co-ordination by showing the over-all multiple-aircraft pattern of operations in the airspace rather than only those aircraft that are nearest the tower and within visual range. In SVFR operations this will also help the tower controller co-ordinate with the centre controller on airspace changeovers between SVFR and IFR operations.

Enh. 9: Establish ADS-B Separation Standards

Current automation is limited in providing benefits to users based on existing radar accuracy. This enhancement will integrate ADS-B data with radar and conflict alert automation to determine if today's separation standards can be achieved or reduced. Ultimately ADS-B will be integrated with advanced decision support automation. The expected benefits are the following:

- Better controller awareness of equipped traffic actual positions
- Improved ability for radar automation systems to estimate aircraft trajectories (e.g., conflict alert, minimum safe altitude warning)
- Higher surveillance system availability
- More efficient application of separation standards
- More accurate traffic advisories by controller to pilots

App. 9.1.1 Radar augmentation with ADS-to support mixed equipage in terminal airspace
This application integrates ADS-B data with radar data to increase the accuracy and availability of multi-sensor surveillance information in the terminal airspace. Air-to-ground ADS-B messages will contribute to the identification and tracking of ADS-B equipped aircraft when data from multiple sensors is processed for display to the controller. ADS-B will also provide a back-up to radar sensors in the event of sensor outage. This application will evaluate the ADS-B accuracy, integrity,

and availability for provision of radar-like services as well as the procedures that deal with mixed equipage airspace.

App. 9.2.1 Radar augmentation with ADS-B to support mixed equipage in en route airspace
This application integrates ADS-B data with radar data to increase the accuracy and availability of multi-sensor surveillance information in the en route airspace. Air-to-ground ADS-B messages will contribute to the identification and tracking of ADS-B equipped aircraft when data from multiple sensors is processed for display to the controller. ADS-B will also provide a back-up to radar sensors in the event of sensor outage. This application will evaluate the ADS-B accuracy, integrity, and availability for provision of radar-like services as well as the procedures that deal with mixed equipage airspace.

Application Traceability

Current Applications

The applications listed above have evolved since the August 1998 *Roadmap* was completed. In the process of identifying stakeholders who will support the evaluation of the applications and resources necessary to support the applications within the next two years, the applications were prioritized and some of the applications were dropped from the list. Section 4 of the Master Plan goes into the details of the current application priorities.

These applications have a history related to the Government/Industry Operational Concept, the Air Traffic Concept of Operations, and RTCA's ADS-B MASPS.

Previous Applications Not Evaluated by 2002

There are several reasons why an application will not be evaluated by the Safe Flight 21 program. One of those reasons is that, due to resource constraints, the application cannot be evaluated until after 2002. For example, applications 6.3 and 9.3 are important to the stakeholders but fell outside of the Safe Flight 21 programme plan to evaluate the applications between FY99 and FY02.

Previous Application Eliminated

The remainder of the applications the stakeholders view as not as important to them as the previous applications. The issues involved with application 3.3 (Enhanced parallel approaches in VMC/MVMC) are addressed to some degree in applications 3.1 and 3.2 (Enhanced visual approaches and final approach spacing). Application 4.2 is really a combination of the other 4.x applications. Applications 5.1, 5.3, 5.4, and 5.5 are of marginal short-term benefit except in oceanic airspace, which is outside the scope of Safe Flight 21.

A.26 TELSACS

A.26.1 Objectives

The 4th Framework TELSACS (TELematics for SAfety Critical Systems) project has been tasked by the Directorate General DGXIII of the European Commission under Contract-No. TR 1055. The project was co-ordinated by Dassault Electronique. Further team members were Aena, Alcatel ISR, Alenia Sistemi, Daimler-Benz Aerospace, Iberia, Indra and National Avionics. The duration of the project was from 01/01/96 until 31/08/99.

Today, decision-making regarding anti-collision between aircraft relies on information coming from two systems:

- Short Term Conflict Alert (STCA), on the ground: Controllers are assisted in their work by STCA services, notifying current or predicted conflicts between aircraft, based on ATC radar information,
- Airborne Collision Avoidance System (ACAS), aboard equipped aircraft: Pilots are informed of neighbouring traffic and provided by ACAS with advisories to maintain or increase separation with threatening aircraft.

The analysis of conflicts presenting ACAS events shows that pilot and controller perceptions of the situation are very different and even that there can be a complete misunderstanding in some cases. Data link enables data exchange between aircraft and ground, which contributes to enhance both users' understanding of the conflict situation, based on the existing ACAS and STCA, which is necessary to improve their interoperability. TELSACS (TELematics for SAfety Critical Systems) project focused on the use of airborne and ground “safety nets” in a interoperable way aiming at enhancing the overall level of air safety, and at reducing the disturbing effects. A primary goal was to improve user awareness, both on the ground and on board. Additionally, current functions and display were enhanced to meet user requirements.

It was establish as TELSACS objective that ACAS and STCA must be independent between them. For this reason interoperable must be understood as co-operation and no as dependent.

TELSACS objectives were derived from end users' expectations and needs, collected by means of interviews and also from the study of ACAS evaluation in Europe. Synthetically, end users experience some dysfunction and request additional information or aids:

- Though controllers consider that ACAS enhances the overall level of safety, ACAS alerts may appear as disturbing for them :
- because they induce pilots to issue additional requests for traffic information, which increases controllers' workload,
- because RAs provoke unexpected aircraft behaviour which, due to the surprise effect, is stressing for the controller, disrupts his/her activities and in some cases may produce new hazardous situation.

Besides:

- ACAS sometimes triggers on situations, which are already well managed by controllers.
- It takes some time to the controller to realise that the clearances he/she has given are not followed, since the aircraft deviations are not immediately detected (due to radar update rate and vertical precision).
- Controllers request a reduction of disturbing effects and to be provided with conflict resolution aids.
- Pilots' main objective is the improvement of safety, obtained through :
- the enhancement of general situation awareness on-board,
- a reduction of false alarm rate.

The project's lifecycle included five phases, having put the stress on validation, which was achieved by way of co-operation with users. The five phases were:

- WP10: Drafting specifications of requirements with pilots and controllers, collected by means of interviews.
- WP20: Specifications of the safety system merging the ACAS and STCA functions,
- WP30: development of a demonstrator on the AENA platform enabling performance measurement and evaluation.
- WP40: Perform a feasibility study on the simulator on Alcatel ISR and the validation study on the demonstrator on the AENA platform (involving pilots and controllers).
- WP50: Setting up an exploitation plan after the recommendations having been written.

A.26.2 Method used

The activities performed in the TELSCAS project life cycle was applied in four phases:

- User Requirements Definition: through surveys to controllers and pilots from several European countries as well as with the study of true situations in which TA/RA messages appeared in order to define a set of representative scenarios that were run during the simulations.
- System Specifications: paper study to produce a validation plan that was used to perform the validation process, identifying of users and validation objectives, system performances, success factors and demonstrator test plan.
- Demonstrator: it was built a platform to demonstrate the objectives of the TELSACS environment with real time simulations, involving pilots and controllers.
- Project Assessment.

A series of performance parameters are used to evaluate the TELSACS System. These parameters were measured during simulation and demonstration session and include the following:

- Measured safety criteria, including number of conflicts and number of violations of separation standards.
- Analysis of conflicts and/or air-miss conditions, considering aircraft configuration and alerts triggered on both the STCA and ACAS safety nets (whether or not they occurred, the amount of advance notice given)
- Quantifiable parameters of the systems, including number of STCA alerts, number of STCA false alerts, advance notice given of STCA, number of TAs/RAs, number of moderate TAs/RAs and number of unwarranted TAs/RAs.
- Analysis of manoeuvres, including number of aircraft deviations linked to collision avoidance and the delay in detecting a deviation.

In addition to measuring these parameters, user acceptance will be assessed, by means of experimentation and questionnaires. The objective of this assessment is to gather user opinions of the additional services provided by the TELSACS system, the suitability of the HMI, safety and the reduction in their workload.

The evaluation of the concepts proposed in TELSACS Project was been carried out performing two different kinds of analysis.

The first analysis was based on a statistical approach allowing the definition and execution of a large number of simulation exercises characterised by several values of input and control parameters. It enables the analyser to stress the system from several points of view and to model extreme situations hardly to reproduce in a real time environment with the “man-in-the-loop” involvement. The platform used for the analysis was POSEIDON, a distributed interactive simulation (DIS) system developed by ISR. Its primary objectives are to ensure :

It enables development of simulation including a great number of entities, thus enabling datalink sizing.

The models behave independently from each other and communicate using a standard (DIS).

The second kind of analysis used to evaluate the benefits of TELSACS is based on the interpretation of the results of real time simulations performed involving Air Traffic Controllers and pilots. The platform used to analyse the system from this point of view was AENA’s SACTA (Spanish Air Traffic Control Automated System) pre-operational platform. The variety of the actors involved in the experimentation does not allow the full control of the variables and the repetition of identical situations; in this case the results analysis became more complex and requires the application of different methods: objective (analysis of recorded simulation data) and subjective ones. The subjective analysis represents the basis for the user’s acceptance evaluation.

The principle with which the evaluation was carried out by means of both POSEIDON and SACTA consists of

- the execution of some scenarios representing several conflict situations with and without the enhancements defined in the TELSACS project, and
- the comparison of the results of the scenarios execution

As said above the demonstration performed on SACTA platform were used to perform a technical validation of the system with the users involvement and to analyse from an operational point of view the benefits deriving from the use of the enhancements implemented in the TELSACS system. In fact following demonstration sessions the users were invited to discuss about their feeling on the system and to fill a questionnaire to be used as the basis for the subjective analysis.

The subjective analysis allows defining the degree of the users acceptance in terms of:

- their feeling on enhancements provided by TELSACS and on way the additional information is provided, and
- To evaluate the benefits in terms of safety and controllers and pilots workload.

A.26.3 Main Results

Main enhancements of short-term anti-collision system on the **ground** were:

- Improvement of air situation knowledge and existing STCA functions (trajectory prediction, conflict detection and alert) using downlinked aircraft kinematics data (main input improvements) decreasing of the number of the conflict detected by the STCA and, most important, a decrease of the number of alerts and false alert due to the use on ground more accurate data from air.
- Awareness and use of ACAS advisories on the ground, through the use with data exchange related to anti-collision, with the airborne system. The results showed a decrease of the deviation detection delay and the added window with the TA/Ras messages showed to the controller allowed the controller to improve his situation awareness.
- Enhancement of controller's HMI, especially related to awareness of ACAS advisories and their consequences (i.e. flight deviations) were positively judge by controllers.

Main TELSACS enhancements from the current ACAS were:

- Improvement of the surveillance function, which will provide to collision avoidance logic additional and more accurate input data about intruder. The surveillance function will take advantage of both air-air data exchange by means of ADS-B, which provides to ACAS additional and more accurate data (position, kinematics, intents, ...) and uplinked information from ground about: information that ADS-B cannot provide (altitude for intruders which are non-altitude reporting and cleared flight level).
- Extension of current collision avoidance logic function, using uplinked intruder cleared flight level.
- Enhancement of pilot's HMI, especially related to situation awareness in order to anticipate the intruder trajectory and decrease pilot workload (display of traffic information).

From a controller point of view, significant benefits coming from the use of TELSACS system were the increased level of confidence in aircraft position, safety net and STCA warning time due to the improved information support providing integration of both air and ground systems. This had as consequence a relevant improvement of the air situation awareness. In addition, no one of controllers declared to have been disturbed by TELSACS conflict alert tool more than current STCA; and in particular the reduction of the false alarm rate and the automatic transmission of traffic information to the aircraft reduce the controller's workload (even if additional training was required if a significant reduction of workload would be reached). The use of colours, shapes and sizes employed to display conflict situations, and in general all the HMI improvements, was found good/very good by controllers.

From a pilot's point of view had a very positive opinion on enhancements and improvements provided by the TELSACS. In particular, all of them retained full satisfactory both the implemented cockpit panel. The use of the CFL(Clearance Flight Level)/SFL(Selected Flight Level) to modulate the relevance of a TA/RA was considered by the majority of pilots useful to suppress the moderate TA/RA due to the fact that most of the time they represent unwarranted TA/RA; however there is no unanimity on this aspect. Pilots were generally satisfied also for the way the TA/RA information was shown (displayed labels, symbols, texts, colours, etc.); in addition most of the visual enhancements proposed during the simulations (i.e. display of up-linked CFL) were appreciated and found useful/very useful by the majority of pilots. Regarding the pilots' workload it was a common opinion that at this stage of the system an amount of work similar or minor to the current operational system is needed. All interviewed pilots declared to approve a possible introduction of part of the TELSACS HMI improvements in the real operational cockpit, one third of them would transfer all the HMI improvements as a whole.

A.26.4 Key Concepts and Requirements Identified

The results of TELSACS could be used for the development work in AFAS, above all with HMI issues and communications aspects related with anti-collision systems.

Regarding to the future CNS/ATM technology the following key concepts have been validated (at least partially):

- Automatic Dependent Surveillance (ADS) function related to information useable for the anti-collision purposes.
- Air-ground, air-air communications functions allowing the transfer of various messages related to flight position, identification, bearing, ACAS events and others used by STCA and ACAS systems.
- Airborne and ground HMI to handle the improvements in the anti-collision communications, taking advantage of the interoperability of ACAS and STCA.

The following key requirements have been work out in TELSACS project:

- Onboard HMI shall incorporate information received via data link into the overall TCAS presentation (e.g. call-sign, speed vector, own SFL/CFL compliance)
- Onboard ACAS system shall be capable to use SFL to avoid unwarranted resolutions advisories (RA).
- Onboard ACAS system shall be capable to receive, presents and process messages from the ground and generate flight information to send to ground.
- Controller HMI shall incorporate information received via data link on the window to present the new information (e.g. RA/TA events and associated information)

STCA system shall be capable to receive, presents and process messages from the ground and generate information of surrounding flights to send to air.

A.27 TORCH

A.27.1 Objectives

The main objective of the TORCH Project is the delivery of a viable, consolidated operational concept for the year 2005 onwards[1], which is both coherent with and complementary to the ATM 2000+ Strategy.

The TORCH Operational Concept is based on the EUROCONTROL EATMS OCD and the ATM 2000+ Strategy. TORCH has adopted the EUROCONTROL target concept to derive feasible ideas, or concepts, which could be implemented in the medium term, before the OCD Target Concept timeframe.

The TORCH Project has produced an Operational Concept which may contribute to the seven main objectives included in the OCD and ATM Strategy 2000+ documents. The TORCH Operational Concept aims to contribute to these seven objectives, but it has been felt necessary to establish a prioritisation to focus on the most important objectives. The result of this prioritisation is that Capacity, Safety and Economics have been chosen as the main objectives. Capacity has been identified in the TORCH project as the most critical objective - aside from Safety, which always will be considered as a first priority objective – because of the capacity problems in Europe.

The three TORCH objectives are briefly defined in the following subsections.

A.27.1.1 Safety

The TORCH objective of safety is defined as follows: "To improve safety by ensuring that the number of ATM-induced accidents and serious or risk-bearing incidents does not increase and where possible decrease".

ATM services aim to ensure the safe separation of aircraft both in the air and on the ground

A.27.1.2 Capacity

The TORCH objective of capacity is defined as follows :

- "To provide sufficient capacity to accommodate the demand in typical busy hour periods without imposing significant operational, economic or environmental penalties under normal circumstances
- To enable airports to make the best use of possible capacity, as determined by the infrastructure in place (land-side and air-side), political and environmental restrictions, and the economic handling of the traffic demand".

The TORCH capacity objective can be met by avoiding the main causes of capacity shortfall: the workload for at least one operator, communications, the route network, sectorisation, airport capacity, separations, and the number of staff.

A.27.1.3 Economics

The TORCH objective of Economics is defined as follows: "To reduce the direct and indirect ATM-related costs per unit of aircraft operations".

[1] "2005 onwards" can be interpreted as 2005-2010

Economic considerations should be an integral part of the development, implementation, operational and cost-recovery stages to ensure prioritisation of the allocation and usage of capital and resources at each decision stage. Cost reduction and value-for-money must be essential elements for ATM.

Cost-effectiveness appears in the TORCH Objective called Economics as the main target to be achieved through ATM Service Provider and Aircraft Operator Cost Savings.

A.27.2 Methods Used

A.27.2.1 Introduction

An assessment of the resulting operational concept is needed for three reasons: to determine the feasibility of the operational concept; to quantify the benefits and costs associated to its implementation; and to increase the confidence regarding the implementation of the concept. The assessment phase fulfils a very important objective of the TORCH project: to ensure that the operational concept that is being proposed can be implemented within the target timeframe.

Certainty on the feasibility of the operational concept will be elaborated from three different points of view: operational, technical and socio-economical. Through these three points of view TORCH will prove the viability of the proposed concept, quantify the expected benefits in terms of TORCH objectives (safety, capacity and efficiency), select and recommend the most promising elements and ensure the compatibility and consistency of the proposed operational concept.

A.27.2.2 Assessed operational concept elements

Since the TORCH Operational Concept covers a broad range of subjects, and to ensure the optimisation of the available resources, the TORCH project will not assess all the elements that form the Operational Concept. Instead, TORCH will consider only those elements whose required operational changes are possible within TORCH timeframe, focusing on issues that seem to be new and not already covered by other projects and that do not require extensive simulations and/or trials.

A.27.2.3 Operational assessment

Objectives
The operational assessment of the proposed TORCH operational concept will prove the feasibility of the operational concept from an operational point of view. To achieve this objective the assessment will quantify the expected benefits in terms of capacity, safety and efficiency.

Methodology
TORCH will prepare the scenarios to be assessed through the identification of the objectives, the performance targets and the changes to the existing ATM system that have to be checked. The scenarios will be completed through the selection of indicators and metrics and the definition of the assessment scope.

The identification of the objectives, the performance targets and the proposed changes will enable TORCH to produce a list of indicators and metrics that address them. The metrics will be based on a list of assessment tools selected on the basis of their adequacy to the evaluation of the selected objectives, performance targets and proposed changes.

Operational assessment of the scenarios will be performed through a multidisciplinary approach. Through this approach, TORCH ensures that all operational aspects are considered. The multidisciplinary approach will use three different types of assessment to ensure the completeness of the operational assessment of the proposed TORCH concept:

- Process Simulation,
- “Paper” studies,
- Fast Time simulation.

Process simulation will be used to show and assess the interdependencies between the different TORCH elements involved in the Operational Concept. This assessment will focus mainly on the planning aspects of the proposed TORCH operational concept and will be used to quantify the benefit potential of TORCH.

Paper studies will consist on “Quality of Service” (QoS) analysis that will ensure the consistency of the proposed solution. The QoS analysis will be concentrated mainly on the issues regarding Airborne Separation Assurance, and specifically Station Keeping in en-route and in the TMA.

Fast Time simulation will quantify the contribution to the TORCH objectives of the proposed solution. This will be done through statistical assessment and workload measurements.

A.27.2.4 Technical assessment

Objectives
The technical assessment of the proposed TORCH operational concept will establish how technical products meet operational concept enablers. The technical assessment will result in a realistic timeline between now and 2010 to make all technical products required by the TORCH concept (i.e. meeting its requirements) available for operational use. The technical assessment will also be used to highlight the technical means that are part of the concept (that is required operationally e.g. tools to be used by operational staff).

Methodology
The technical assessment methodology follows three steps: elaboration of the expected timeline according to current plans and ideas –including expected technical characteristics of products at each step -; mapping to TORCH concept requirements, and shortcoming identification; identification of a new timeline required to make the TORCH concept technically feasible before 2010. These three steps are preceded by two preparation steps through which the assessment methods as well as the assessment tools were selected and described.

Since it is recognised that the TORCH scope is very large –it covers the complete ATM system -, a complete detailed assessment of the technical feasibility of the TORCH concept is unrealistic. Based on the importance of the related TORCH requirements –requirements about what is considered fundamental in the TORCH concept -, and on the most difficult TORCH requirements – i.e. availability of a technical product meeting the TORCH requirement in the time frame -, TORCH will select the products to be assessed.

A.27.2.5 Socio-economic assessment

Objectives
The main objective of the socio-economic assessment is to make certain that the Operational Concept is socio-economically feasible within the TORCH time frame. To achieve this objective the socio-economical assessment must justify socially and economically the selection and viability of the operational concept. This will be done trough the determination of the cost effectiveness and of the social impact of the implementation of the proposed TORCH operational concept.

Methodology

The socio-economic assessment will have two distinct lines of action. The first one will be dedicated to the performance of a cost-effectiveness analysis, and the second one to the evaluation of the social impact. oth the Cost-effectiveness and the social impact analysis will determine the indicators, the scenarios and the expected positive and negative impacts of the implementation of the TORCH concept.

The economic assessment will focus on the effectiveness of the inversions needed to implement TORCH. This assessment will use as a baseline a "do-nothing" scenario in which the expected system in 2005 will be compared against the proposed TORCH system.

The social assessment will investigate the effect of the implementation of TORCH in the various ATM stakeholders. This analysis will be done through the identification and classification of the potential benefits for each stakeholder.

The result of both analysis will be combined to produce a socio-economic assessment that indicates both the economic effectiveness and the social benefit of the TORCH operational concept implementation.

The Delphi Method and the Analytic Hierarchy Process will be applied.

A.27.3 Main Results

Assessment of the TORCH Operational Concept is currently under way. Technical, operational and socio-economic assessments of the concept are currently under way and will be finished by the end of July 2000. At the conclusion of this phase, the result will be an Operational Concept assessed and presented to increase capacity, safety and economical benefits to the ATM community.

A TORCH User Forum to be held on 7/8th June 2000 is under preparation. The TORCH Concept will be presented to the ATM Community and initial conclusions resulting from the assessment phase will be offered according to chapter four of this document.

It is planned that the TORCH Project will be finished by October 2000.

A.27.4 Key Concepts and Requirements Identified

TORCH has designed its operational concept to meet the objectives described. The TORCH Operational Concept focuses on improvements in airspace management and flow management. These two focal points have been selected because they are fields in which potential benefits can be achieved with a minimum amount of effort.

A layered planning phase is proposed, based on more flexible use of airspace and the greater involvement of the ATM actors. The approach taken is to optimise the management of available resources instead of constraining demand.

The TORCH Operational Concept consists of 18 elements, which have been grouped into seven clusters: From Strategic Planning to Real-Time Optimisation, Local Air Traffic Flow Management, Tactical Traffic Control, Airline Operations, Airport Operations, Performance Management and Information Management. These clusters comprise all of the phases of flight and all of the actors involved in ATM processes.

From Strategic Planning to Real-Time Optimisation. In this cluster of elements, the most significant TORCH proposal is to develop a Daily Operational Plan (DOP) through the dynamic use of Collaborative Decision Making (CDM). This plan is developed on the basis of the information contained in the Strategic Plan, established one year in advance of the day of operation. Until the day of operation, the layered planning process will continuously receive real-time updates to changing parameters, making the decision-making loop more sensitive to different stakeholder needs.

Using CDM procedures, the DOP will be updated to create a more accurate picture of the current situation, taking into account real-time changes that can affect the stakeholders' expectations. New possibilities based on the DOP, such as slot-shifting, slot-swapping or re-routing, will broaden the range of solutions available to solve a given problem.

The DOP process will improve the tactical planning phase, bridging the current gap between the Central Flight Management Unit (CFMU) and air traffic control (ATC). The increased accuracy and dynamic planning made possible by the DOP will increase efficiency, in the sense of improved use of physical capacity.

Local ATFM. This cluster of elements includes En-Route Planning and Terminal Area Sequencing. En-Route Planning will act as a bridge between flow and capacity management, and tactical ATC, based on the information provided by the DOP. Terminal Area Sequencing will match the planned approach and departure sequences to optimise TMA resources, through co-ordination between the stakeholders involved in the process.

Tactical Traffic Control. This cluster of elements includes Separation Assurance and Hazard Assessment. During the TORCH timeframe, responsibility for Separation Assurance may be delegated to the aircrews of suitably-equipped aircraft. This delegation may be partial (in Managed Air Space) or total (in Free Flight Air Space). Conflicts will be detected by the ground system, which will propose conflict resolution strategies. Hazard Assessment will be based on improved safety net functions (Short-Term Conflict Alert, Area Proximity Warning, Minimum Safe Altitude Warning and Airborne Collision Avoidance).

Airline Operations. Airline operators will become more involved in planning and will make decisions together with ATC and the CFMU. They will negotiate their plans during the planning phase and exchange information with other stakeholders. Real-time data will be used to optimise fleet operations. Schedules and routes will be closer to user preferences, improving the general predictability of the system.

Airport Operations. These operations will be more integrated in the overall ATM process than at present. ATFM measures and airport capacities will be linked during all planning phases. Co-ordination with the en-route planning phase will support the uninterrupted gate-to-gate operations.

TORCH Operational Concept has been defined as a transition from the current constrained ATM system and the Target Concept proposed in EUROCONTROL's Operational Concept Document.

Further information about the methodology adopted by the TORCH Project and lower level descriptions can be found in the TORCH website (www.isdefe.es/torch/torch.htm).

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