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DADI – Datalinking of Aircraft-Derived Information

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Abstract

The initial 'DADI' project, which took a fresh look at the pre-operational exploitation of aircraft data by ground-based ATM applications to enhance airspace capacity and safety, has been completed. The project brought together several European Research Establishments, ATC Authorities, Manufacturers and Air Operators in four complementary investigations. The four investigations included:- 1) a French evaluation to exploit Mode S Specific Services in high traffic density European airspace; 2) a Norwegian evaluation to exploit satellite-based ADS for helicopter operations outside radar coverage over the North Sea; 3) a Dutch simulation of ATC in high traffic density airspace; 4) a Dutch validation model for capacity and safety analysis. Technical verification of all four developments has been completed, and initial evaluation results indicate that significant benefits can be realised. The sequel to this project, 'DADI-2', which plans to develop and exploit the existing DADI facilities, has recently started.

1. Background

It has long been recognised that digital systems in modern aircraft could provide a great deal of information of significant value to ATM applications on the ground. The development of ADS and its potential exploitation in the Atlantic and Pacific oceanic areas has already highlighted the value of this approach in areas of low aircraft density. However, although a lot has been said about the possibilities of exploiting aircraft data in order to improve both capacity and safety in high density continental airspace, and a few practical demonstrations of specific uses have been made, little has been done to assess the practicalities and benefits of implementation in near-term environments. The 'DADI' (Datalinking of Aircraft Derived Information) project has attempted to fill this gap, and has achieved some notable progress.

2. Overview of DADI

DADI was a collaborative project organised and part-funded through the EC Framework 4 Programme. The collaborators were NLR (Project Co-ordinator), DERA, Sofréavia, Kongsberg, NCAA, STNA, British Airways, Airsys ATM and Air France. The project ran from January 1998 to December 1999.

The ultimate objective of DADI was to contribute to the enhancement of airspace capacity and safety, by evaluating the use on the ground of various types of information available from aircraft. The project's approach to this 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 for improved control of helicopter operations over the North Sea, beyond the range of radar. The French evaluation site was based around the Mode S facilities at Toulouse, and made significant use of the DERA BAC 1-11 'flying laboratory'. The Netherlands evaluation was based on real-time simulation, and was designed to qualify and quantify the benefits of aircraft data in surveillance and medium-term trajectory prediction in high air-traffic density airspace. By performing evaluations involving real aircraft installations and ground facilities, a tremendous insight is achieved into a wide range of practical and operational issues, but the work is limited by the small numbers of participating aircraft. By performing complementary real-time simulations, greater flexibility is possible, and a range of future scenarios can be evaluated with varying traffic loads and equipment fits in the simulated aircraft.

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. This topic is the subject of a separate ATM 2000 paper, so will not be discussed further here.

To ensure coherence between all the DADI evaluations, a common approach was adopted for the initial assessment of User Requirements and System Architectures, and then standardised procedures were developed for defining the system specifications, for planning the individual validations and for analysing the experimental results.

Validation of systems such as the DADI Sites involves two distinct processes. The first stage, often referred to as 'verification', confirms that the technical performance of the facilities is in accordance with the system specification, i.e. "Does it all work as defined?" The second stage, often referred to as 'evaluation', involves extensive trials designed to optimise the use of the systems and to quantify the benefits provided, i.e. "How useful is it?" Due to budgetary constraints, the DADI project discussed here could complete only the first 'verification' stage. However, a subsequent proposal for a follow-on project, known as 'DADI-2', has been accepted by the European Commission and will be jointly funded by the EC and the Consortium. This will permit the second stage 'evaluation' of the DADI facilities, as well as some technical enhancements to the evaluation sites. DADI-2 commenced at the beginning of 2000 and will be completed in 30 months.

One very important aspect of all EC 4th Framework projects is the dissemination of the knowledge gained during the project. A DADI work package was therefore set up to ensure that effective information exchange was achieved, not only with other 4th Framework projects, but also with the relevant EUROCONTROL and ICAO committees. Throughout its life, the DADI Project has made significant impacts on the international scene.

The following sections of this document provide descriptions of the various activities that were integrated within the DADI project, together with outlines of the results of the verification tests, as follows:

- Section 3 discusses the analysis performed in order to clarify the 'User Requirements' that were used as input information in the design of the evaluation sites.
- Section 4 deals with the analysis of the air, ground and communications architectures that were considered for the DADI developments.
- Section 5 describes the French evaluation site together with the UK BAC 1-11 aircraft used for the exploitation of the Mode S Specific Services.
- Section 6 discusses the Norwegian evaluation site, which developed the use of ADS for helicopter operations off the western Norwegian coast.
- Section 7 deals with the exploitation of the NLR real-time simulator for evaluation of the use of DAPs transferred via various air-ground communications technologies.
- Section 8 mentions the most important dissemination activities undertaken.
- Section 9 provides an outline of the successor project, 'DADI-2'.
- Section 10 gives a brief summary of the interim conclusions of DADI.
- Section 11 provides a Glossary of abbreviations.

3. User Requirements

The principal objectives of this activity were three-fold:

1. To provide a general review of the existing literature concerning potential uses of aircraft data in a wide range of scenarios and timescales;
2. To provide guidance to subsequent DADI work packages on the specific uses of aircraft data within their chosen scenarios;
3. To make recommendations where appropriate to other European groups, based on the harmonisation of information obtained from work on Objective 1.

Firstly, an overview was derived of the requirements for air-ground data exchange, both from the global (ICAO) and from the European (EATCHIP) perspectives. Next 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 attempted to provide the detailed specification of user requirements that was needed. Consequently, two further activities were undertaken. In the first, a group of French controllers took part in a survey to identify their perceived needs for aircraft data. In the second, a detailed analysis was performed of the potential use of aircraft data to enhance two 'safety net' functions, namely STCA (Short Term Conflict Alert) and MSAW (Minimum Safe Altitude Warning).

Finally, 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.

4. System Architectures

The initial objective of this work package 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. Following this, a review was performed of the architectures of ground and airborne system architectures, concentrating on those available in a European context. Finally, 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.

5. The French ATC Evaluation Site

The French Evaluation Site focused on support to ATM in high traffic density en-route airspace representative of Central Europe. The emphasis was on exploiting the Mode S Specific Services in a realistic pre-operational environment, so that results could be compared with the ATN-based results from WP5.

The principal objectives of this evaluation site were:

- To develop the concept of a 'Datalink Server', providing a comprehensive interface between the ground-based applications and the air-ground communications systems;
- To exploit the various air-ground communications protocols made available through the 'Mode S Specific Services';
- To develop an example of 'Human Access to Aircraft Derived Information' (HAADI), where the impact of DAP data could be assessed
- To develop an example of 'Computer Access to Aircraft Derived Information' (CAADI), where the impact of DAP data could be assessed.

The chosen HAADI application was the display of aircraft data on the ATCO's display, often referred to as 'CAP' (Controller Access to Parameters) where the selection of parameters and the means of display could be investigated. The chosen CAADI application was 'MSAW' (Minimum Safe Altitude Warning), where the performance improvement using aircraft data (such as Selected Flight Level) could be investigated.

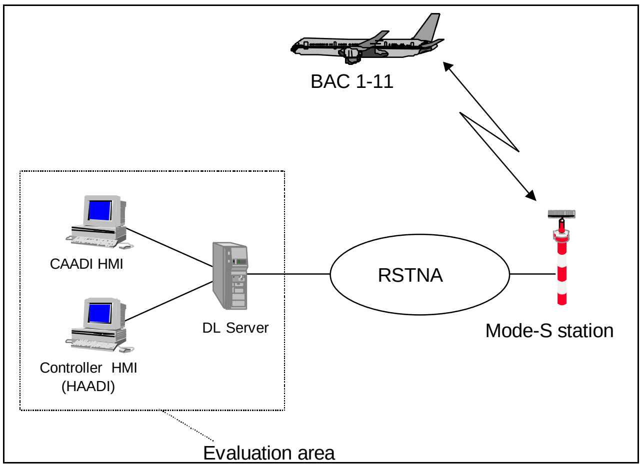

Figure 1: Schematic of the French Evaluation System

The ground-based evaluation site was centred on the STNA facilities at Toulouse in southern France. The main sub-systems, shown diagrammatically in Figure 1, comprised:

- The Mode S radar ground station, already fully developed;
- The 'RSTNA' ground communications network;
- The Ground Mode S Data Link Server, built for DADI by Airsys ATM, 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 MSAW evaluation system, built for DADI.

Three particular services that exploited protocols of the Mode S Specific Services were investigated:

- Contracts with the Datalink Server for 'Periodic' GICB reports;
- 'On Demand' requests for individual GICB reports;
- Contracts with the ADLP for 'On Event' AICB reports, known as '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 based at Boscombe Down, UK. 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'.

Following successful ground testing of all the newly developed facilities, the BAC 1-11 flew to Toulouse where a series of end-to-end trials took place between 21 and 25 June 1999. The trials included a mixture of testing with the aircraft on the tarmac together with 4 dedicated flights totalling about 4 hours of flying time within cover of the Mode S radar. For each flight, the flight plan and the schedule of interrogations were carefully designed to support verification not only of the technical performance of the systems but also of the CAADI and HAADI applications.

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 – sufficient for initial analysis.

The aircraft parameters that were investigated, and the BDS registers from which 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 preliminary analysis of system performance has proved most encouraging. All the equipment operated reliably throughout the flight trials and (with one minor exception) all the message protocols were implemented correctly. Initial analysis has shown that the characteristics of the downlinked data were appropriate for the target applications.

Some features of the results were linked to the rather long (8.1 second) rotation period of the Toulouse Mode S radar, and its scheduling/duty cycle limitation of only 4 GICB interrogations per aircraft per aerial rotation. In addition, its channel management function was designed to require two aerial rotations to extract AICB messages, such as are used for the Dataflash reports. However, none of these problems was sufficiently serious to invalidate the trials or the concepts investigated. In particular, the transfer of data from aircraft to ground applications took place with no corruptions.

Considerable improvement would be expected with the design of the POEMS stations, which allows for shorter rotation periods, more interrogations per aircraft, and the extraction of AICBs during a single aerial rotation. Such improvements would facilitate considerably better Dataflash performance. Reports have been prepared for SICASP, identifying some aspects of the Dataflash Service that could be improved, and for EUROCONTROL, identifying some minor errors in the Dataflash implementation in the ADLP.

During the flight trials, the prototype controller's HMI was demonstrated to operational controllers. Their general conclusions were that the extra data displayed is potentially useful for both en-route and approach control purposes, but that some improvements in the HMI are required. Also, aircraft data must be acquired from the most appropriate aircraft source, an example being Vertical Rate, where the chosen source proved too noisy.

The evaluation of the CAADI application 'MSAW' was somewhat inconclusive, owing to two shortcomings of the trials system. MSAW relies essentially on knowledge of the vertical trajectory to predict potential conflicts with the terrain. Neither of the two aircraft parameters that could assist MSAW predictions were fully optimised:

- changes to Selected FL, communicated via Dataflash, suffered an unnecessary delay of one aerial rotation caused by the implementation of the AICB protocol in the ground station;
- Vertical Rate, although available promptly through the 'Periodic Report' protocol, came from a noisy aircraft source.

Evaluation of potential improvements to MSAW must therefore be deferred until both issues are addressed.

The general conclusion from these trials is that an extremely useful set of facilities now exists. With a few minor improvements, this facility can make a major contribution to the future exploitation of aircraft data.

6. ADS for Helicopter Operations

The Norwegian demonstrator has evaluated satellite communications for downlinking aircraft derived information from helicopters in remote areas that are without other means of surveillance. Such an operating environment is experienced by off-shore helicopters serving the oil installations in the North Sea and northern Norwegian waters. This DADI development was based on M-ADS (Modified ADS), and has been developed by Kongsberg Defence & Aerospace and the Norwegian CAA (NCAA), making use of ATN-based communication via BT Skyphone using Inmarsat satellites.

The principal objectives of this evaluation were:

- To make use of the ADS Contract (ADS-C) concept via an ATN datalink for real-time transfer of DAP data from helicopters to ATC Centres;
- To implement these concepts both in NCAA Operational Centres and in the Kongsberg experimental facilities;
- To equip a representative number of helicopters to participate in the evaluations;
- To exploit the downlinked data for both HAADI and CAADI applications.

The HAADI applications chosen for this evaluation were directed principally at the ATCO to enable surveillance beyond the range of SSR, to provide rapid response and enhanced safety in emergency situations, and to support improved Flight Information Services.

The CAADI applications included automatic monitoring for the Emergency Alerting Service and for non-compliance with contracted ADS reporting rates.

Figure 2 shows a schematic diagram of the facilities employed.

The ground-based facilities included three specially adapted ATCO displays for both ADS and radar data, two being integrated with the operational facilities at the Bodø and Stavanger ATCCs, while the third was in the NCAA Røyken laboratories.

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, longer messages) for down-link.

All downlink communications were via the ADS Contract protocol, using both 'periodic' and 'event' contracts. The ATCOs were provided with facilities to change both the requested reporting periods and parameters from the default contract settings, to request single reports, and to define 'event' contracts.

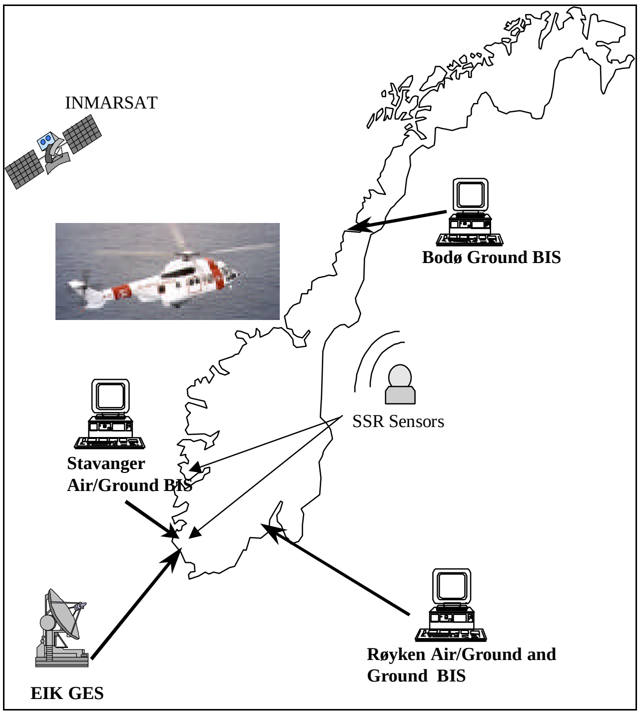

Figure 2: The Norwegian evaluation system

The M-ADS (Modified ADS) specification includes all the standard ADS Message Groups, but adds an 'SSR Data Group' comprising SSR Code, SSR Transponder Status and Aircraft Air/Ground Status. The three main purposes of these enhancements are:

- to facilitate transitions between radar and ADS airspace;
- to support detection of emergencies through use of the SSR codes 7500, 7600 and 7700;
- to confirm when helicopters have landed on or have left remote platforms.

The airborne installations comprised the appropriate Aircraft Earth Station for the satellite communications, plus the M-ADS unit which interfaced to the existing helicopter data sources and managed the construction and decoding of messages. During the period of this project, the number of commercial helicopters equipped to participate built up to a total of 9, operating in the Stavanger, Trondheim and Bodø FIRs. In addition, the helicopter simulator in the NCAA Røyken laboratories was used throughout.

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

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).

The data required for the planned analysis of system performance during FIR Boundary Crossings has not yet been obtained.

It must be emphasised that the above statistics and observations have been obtained during the development phase, and many recommendations for system, operational and trials improvements have been developed which should ensure considerably better subsequent performance. Nevertheless, the results to date of this evaluation strongly support the use of satellite-based ADS and the concepts of CAADI and HAADI for helicopter operations in non-radar airspace.

7. DAP Evaluation at a Simulated ATC Site

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 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.

The principal objectives of this activity were:

- to enhance NARSIM for evaluation of options for the exploitation of DAP in high density airspace;
- to evaluate HAADI applications, such as the presentation of aircraft data to ATCOs;
- to evaluate CAADI applications, such as surveillance and tracking, STCA, MSAW and Trajectory Prediction (TP).

Based on an advanced Client/Server architecture, the simulation processes in NARSIM are executed by a set of interconnected servers, as illustrated in Figure 3.

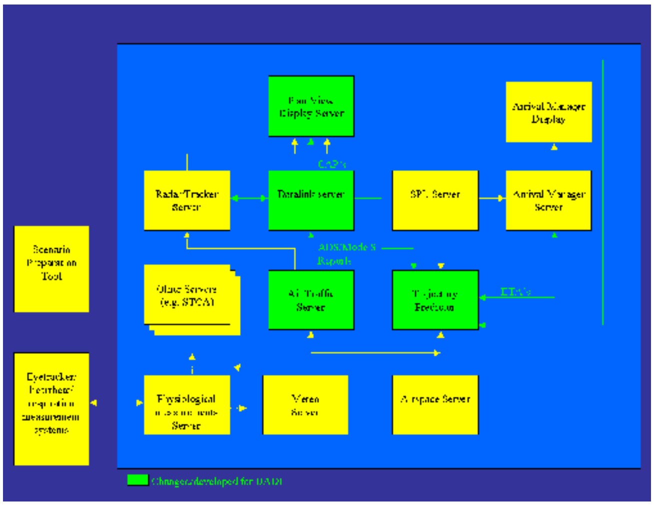

Figure 3: NARSIM Architecture

The principal servers that required development or extension for DADI included:

- *Air Traffic Server:* generates simulated air traffic, enhanced to provide the ground with realistic DAP data;
- *Datalink Server:* accurately models datalink services, specially developed to include VDL Mode 2 (ATN compliant), plus Mode S Specific Services;
- *Ground TP Server:* provides forecasts of trajectories to be flown, specifically enhanced to exploit DAP data, to support medium term planning applications such as Conflict Probe, Arrivals Management and Flight Path Monitoring;
- *Plan View Display Server:* presents surveillance, control and planning information to ATCOs, specifically enhanced to include DAP data in the plot labels.

In addition, other servers in NARSIM of major relevance to DADI, which did not require extensive modification, include:

- *Airspace Server:* provides navigational input concerning airspace objects;
- *Meteo Server:* supplies simulated Meteo data to support planning and TP;
- *Radar/track Server:* simulates radar track data;
- *System Flight Plan Server:* maintains all information on planning and control of each flight.

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, Selected Flight Level, Selected Speed and Selected Heading. Communication of 'Selected' parameter values was simulated through Mode S Specific Services only, whereas all other parameters were simulated through either ADS or Mode S Specific Services.

Following the development of the individual servers and their integration within NARSIM, exhaustive tests were performed with two main objectives:

- To establish that the technical specification for the performance of each had been met;
- To confirm that the original specifications were appropriate for the intended uses.

The conclusions of this development are that NARSIM is now capable of performing simulations in a wide range of scenarios, thus enabling many aspects of the exploitation of DAP data to be validated. The various options available include the following:

- Air-ground communications are configurable, supporting technologies such as VDL Mode 2, Satcom and Mode S Specific Services, with realistic transmission characteristics;
- Scenarios requiring a mix of aircraft datalink capabilities can be handled;
- For each aircraft, DAPs can be acquired through Periodic, On-event and On-request contracts (or combinations);
- The platform supports simulations in different types of sectors (e.g. TMA, ACC, En-route, etc.);
- Up to 400 aircraft can be simultaneously handled, permitting traffic densities of more than twice the current maximum;
- Various DAP-enhanced tools are available to support controllers;
- Platform design permits the simulation of models of airborne errors and evaluation of their impact on ground operations.

In addition to this functional flexibility, NARSIM is well equipped with performance evaluation tools, which include:

- Physiological measuring facilities (respiration, heart-rate, etc);
- Eye-tracker;
- Recording of flight performance characteristics;
- Airspace capacity comparisons between scenarios;
- R/T logging;
- Configurable logging of all relevant system events.

In conclusion, 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.

8. Dissemination

The dissemination of information from the DADI project has been treated as of vital importance throughout the period of the work, with many opportunities being taken to inform appropriate bodies of the interim findings of the project.

For example, the initial analysis of user requirements identified several instances where the recommendations of different international groups differed, or were not consistent with either the airborne facilities or air-ground communication standards. These findings, together with recommendations for 'harmonised' solutions, were immediately passed on to the EUROCONTROL ODIAC committee and to SICASP. In addition, many of the DADI participants have taken opportunities to publicise the DADI activities and findings in various national and international committees and working groups.

More comprehensive and universal approaches to dissemination have been developed in two ways. Firstly, an Internet website (http://www.dadi.net/) was launched mid-way through the project and frequently updated as the various work packages progressed. Secondly, a CD-ROM was produced near the end of the project. This contains a vast amount of project information including all project deliverables available at the time, as well as copies of many of the reference documents used as inputs, particularly for the User Requirements and Architecture studies. *(Copies of this CD-ROM will be made available to genuinely interested parties at the ATM2000 conference).*

Full details of all the verification work performed on the three validation sites during the DADI Project is provided in the 'DADI Verification Report', (Ref DADI/WP4-5-6/DADI/DX3/P/1.1, dated 31/12/99).

9. DADI-2

Following the success of what is now frequently called 'DADI-1', the DADI-2 project was launched in January 2000 under the EC 5th Framework Programme. This 30 month project involves a consortium similar to the DADI-1 consortium, led by Airsys ATM and including DERA (Malvern), NLR, Sofréavia, Kongsberg, NCAA and British Airways. It plans to build on the existing three evaluation platforms, aiming towards the short-term and medium-term exploitation of aircraft data in ground ATC systems.

The project will concentrate on three main areas:

- The concept of Open Communication Architecture;
- DAP-enhanced tools;
- Datalink architectures for safety-related DAP applications.

The key issue in these future developments is the evaluation and exploitation of Open Architecture concepts, where ground systems will exploit all communication means made available by the aircraft, in a manner that is transparent to the end-users. In this way, a high quality of service should be maintained, coupled with flexibility and high efficiency.

To meet these objectives, the three DADI platforms will be enhanced as follows:

- The French ATC system will further develop the ground-based datalink server to include both ATN and MSSS communications as part of the Open Architecture concept. Also, the controller's HMI will be upgraded in accordance with the current French operational approach.
- The Norwegian ATC system will be upgraded to include VDL Mode 4 air-ground communications, in order to investigate the value of datalink redundancy in safety critical DAP applications.
- The Dutch ATC simulator, NARSIM, will concentrate on a DAP-enhanced Inbound Scheduler tool, a natural development from the existing Trajectory Prediction tool.

To provide a coherent framework for the technical developments and evaluations, two other key activities are planned:

- A detailed analysis will be performed of the Open Architecture Concept and its benefits, particularly with regard to the DAP requirements of the tools to be exploited in the various evaluation systems.
- A Business Justification will be developed. This will consider in particular the capacity/efficiency benefits and the flexibility of exploiting Open Architectures, and the safety benefits of dual datalinks.

The expected achievement of DADI-2 is to pave the way towards future DAP-enhanced ATM services by:

- defining how datalinks can work in parallel to enhance safety;
- establishing a coherent Open Architecture concept;
- quantifying improvements to controllers' tools and assessing their impact on capacity and safety;
- preparing for the operational implementation of DAP technology with a justified business case.

10. Conclusions

The DADI project, in developing and technically verifying its three Evaluation Systems, has identified a number of inconsistencies in user requirements and technical standards in the use of DAP, which have been reported to standardisation bodies. It has completed the development of a most valuable set of diverse facilities that are now fit for exploitation. It has successfully brought together activities employing different airborne architectures, different air-ground communications systems and different ground applications. It has then ensured, through a common approach to system specification and validation, that all developments can contribute coherently to improvements in ATM. By combining 'real world' evaluation sites with a simulated evaluation site, both technical feasibility and operation at high traffic density have been combined. In addition, the safety studies (discussed elsewhere) have ensured that the approaches taken by the evaluation systems will add to, rather than detract from, the safety and capacity of airspace.

Analysis of the initial data has confirmed the technical capabilities of all systems, and has already provided valuable indications of the practical benefits and scope for further technical improvements. All systems are now ready for extended evaluation of the quantitative benefits that can be offered to future ATC operations, in terms of both capacity and safety.

11. Glossary of Abbreviations

ACC	Area Control Centre
ADLP	Airborne Data Link Processor
ADS	Automatic Dependent Surveillance
AICB	Air-Initiated Comm B
ATCO	Air Traffic Control Officer
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
CAADI	Computer Access to Aircraft-Derived Information
CAP	Controller Access to Parameters
DADI	Datalinking of Aircraft Derived Information
DAP	Downlink of Airborne Parameters
DERA	Defence Evaluation and Research Agency
EATCHIP	European ATC Harmonisation and Implementation Programme
EC	European Commission
FIR	Flight Information Region
FIS	Flight Information Services
FL	Flight Level
FPM	Flight Path Monitor
GICB	Ground-Initiated Comm B
HAADI	Human Access to Aircraft Derived Information
HMI	Human Machine Interface
IAS	Indicated Air Speed
ICAO	International Civil Aviation Organisation
M-ADS	Modified ADS
MSAW	Minimum Safe Altitude Warning
MSSS	Mode S Specific Services
NARSIM	NLR ATC Research Simulator
NCAA	Norwegian Civil Aviation Authority
NLR	Nationaal Lucht-en Ruimtevaart Laboratorium
ODIAC	Operational Development of Integrated Surveillance and A/G Data Communication
POEMS	Pre-Operational European Mode S Station
R/T	Radio Telephony
SICASP	SSR Improvement and Collision Avoidance Systems Panel
STCA	Short Term Conflict Alert
STNA	Service Technique de Navigation Aerienne
TDMA	Time Division Multiple Access
TMA	Terminal Manoeuvring Area
TOPAZ	Traffic Organisation and Perturbation AnalyZer
TP	Trajectory Prediction
VDL	VHF Data Link

12. Biographical Details – Dr. A. J. (Tony) Hughes

For many years Tony worked as a physicist at DERA on such diverse topics as the low temperature electronic structure of metals, laser anemometry, amorphous semiconductor devices and liquid crystal displays. In 1986 he was awarded the Rank Prize for Opto-electronics for his work on liquid crystal displays. At about that time, Tony moved into ATC research at DERA. Since then he has acted as the Deputy Head of the Air Traffic Control Systems Group at DERA, responsible particularly for Mode S Data Link developments. His spare time is wasted photographing European native orchids, singing bass (badly), playing table tennis (worse) and gardening (his garden is a disaster, but he has won a couple of national quizzes)!