ADS MEDITERRANEAN UPGRADE

ADS-MEDUP Final Report

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ABSTRACT

This Document is the Final Report of ADS Mediterranean Upgrade (ADS MEDUP) Programme.

ADS MEDUP has been developed by ENAV (leader), AENA, HCAA, MATS, Eurocontrol, LFV, DFS and co-financed by DGTREN of the European Commission under the TEN-T framework.

The programme has been started in March 2000 and completed in December 2004 with an overall cost of about 16 Million €, with 50 % contribution by the European Commission.

The main objectives of ADS MEDUP were:

- the establishment of an extended air-ground digital data link infrastructure (based on VDL-4);
- the development of ADS-B and other ATM applications (enabled by the above data link);
- the pre-operational flight testing of same;
- the assessment of possible future benefits obtainable in the Mediterranean area;

A further role of ADS MEDUP was to provide the infrastructure for the Mediterranean Free Flight (MFF) Programme, started in year 2000 by the same Partners plus others and to be completed in year 2005.

The VDL-4 network, composed of 8 Ground Stations, covers the major part of Western and Central Mediterranean. Two a/c have been equipped with VDL-4 Transponders and Cockpit Display Units. They have been used to perform technical verifications and pre-operational evaluations (about 85 flight hours).

The interoperability within the various manufacturers of equipment and with the parallel NUP Programme has been tested successfully.

The performances of several data link services (mainly ADS-B, TIS-B, FIS-B and CPDLC) have been tested and evaluated in real airspace and some conclusions extracted for any potential further work, including possible indications for subsequent operational use.

An outline of safety considerations (specific to ADS-B and Data Link) has been prepared together with preliminary economical consideration.

The exploitation plan takes into appropriate account the most indications on operational priorities (Package 1/Stream 1 Applications) and on alternative data link technologies.
## Project Title
ADS MEDITERRANEAN UPGRADE

## Project Acronym
ADS-MEDUP

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1. Executive Summary

1.1-ADS-MEDUP Objectives

The main Objectives of ADS Mediterranean Upgrade Programme (ADS-MEDUP) were clearly identified in the Programme Management Plan (PMP) in its initial release of August 2000[1]. That initial Plan is briefly summarized hereafter.

The overall context was to perform an extensive pre-operational testing of integrated ATM functions, enabled by the deployment of an ADS/DataLink infrastructure over a large homogeneous area, as the Mediterranean one is, with specific traffic patterns and trends.

By this testing, also supported by simulations and other means of analysis, it was planned to investigate the feasibility of new ADS-based ATM functions and optimized procedures that might represent a significant improvement in the overall Air Traffic Management in the Mediterranean airspace in terms of capacity, flexibility, cost effectiveness, safety.

The time horizon was considered to be near and mid term (from 2005-2010 onwards).

VDL Mode 4 was planned as the Air Air and -Air Ground Data Link, not as a definitive technological choice but in order to utilise existing Faraway infrastructure and NUP experience.

The initial set of Objectives as reported above has been maintained while adaptations have been introduced to cope with minor changes in time schedule and with different system deployment constraints.

In several places, discussions of scenarios and problems take also into consideration the significant (but temporary) slow down in air traffic increase from end 2001 (Twin Towers effect) to mid 2002.

The PMP that was updated at the end of year 2002 [2](see its WBS reported at the end of this Executive Summary) gives the overall picture of the deployment realised.

It is recalled that ADS-MEDUP fits appropriately in the context of other studies and experimentations especially NUP and the Eurocontrol ADS Programme. ADS MEDUP also provides the basic infrastructure for the Mediterranean Free Flight (MFF) Programme.

The ADS MEDUP Programme is split in three Phases, namely:

Phase A 1, with a duration of about one and half year, started in March 2000 and was completed at the end of 2002, includes:
- Initial studies, gathering of updated information, definition of operational scenarios, etc;
- Establishment of detailed operational requirements and specifications;
- Development of one prototype for the core applications, according to the specifications established;
- Laboratory testing of the prototype.

Phase A 2, with a duration of about one and half year, partially interlaced with Phase A 1 and was completed at the end of 2003, includes:
- Infrastructure development and their initial deployment (in three pilot sites, two in Italy and one in Spain and in two a/c, one in Italy and one in Spain);
- Pre-operational tests of limited scope and/or area (ground system tests and preliminary verification flights);
- Discussion of interim results and plans for Phase B.

Phase B, with a duration of about two years, partially interlaced with Phase A 2, and was completed at the end of 2004, includes:
- Appropriate updating of scenarios and operational requirements;
• Completion of infrastructure deployment in the different States;
• Pre-operational tests in a wide area context (completion of verification flights, interconnection of ground nodes, interoperability tests);
• Demonstration flights, interviews to users (ATC Controllers and Pilots);
• Final Report including proper considerations on operational benefits, safety, institutional issues, exploitation.

1.2-Review of results and conclusions reached

Within the scope of this Executive Summary, a review of results is reported below with reference to the different objectives.

1.2.1-Infrastructures and Verification Tests

The MEDUP project has deployed an ADS-B infrastructure over the Mediterranean basin composed of 8 VDLm4 Ground Stations (Madrid and Mallorca in Spain; Roma, Cagliari, Padova and Brinsisi in Italy; Luqa in Malta and Monastiri in Greece) connected to 4 shadow mode ATC centres adequately equipped with ADS-B, TIS-B, FIS-B and CPDLC functionalities (Madrid in Spain and Rome, Padova and Brindisi in Italy). All sites are presented in the figure below.

The information is available through additional ISDN lines also to Eurocontrol Experimental Centre, for their AVT and to DFS in their Langen facilities. Via DFS a connection to the NUP Ground Network is available. Interoperable data flow between the MEDUP and NUP infrastructure had been demonstrated and verified several times.

The geographical layout of the MEDUP network is shown in the figure below.

Figure 1- Layout of the ADS-MEDUP network
Using one Italian and one Spanish a/c, each duly equipped with the MEDUP Airborne Platform (MAP) including a Cockpit Display Unit (CDU also named CDTI), a number of verification flight tests have been performed to assess the technical characteristics of the Data Link and of its use as enabler of the different applications/services.

Interoperability among equipment of different transponder manufacturers and different SW developers has been checked successfully within MEDUP and also with the NUP System exploiting a flight over Italy of a NUP a/c. Similarly, other a/c, equipped for the MFF Programme, have flown over the MEDUP infrastructure, exchanging ADS-B and TIS-B information.

The main findings related to coverage for the different services are reported below.

The coverage for **ADS-B** is reasonably in accordance with the one calculated taking into account orographic situation, nearby obstacles and earth curvature as well as transmitter power and receiver sensitivity as available in the transceiver models employed.

When using the limit criterion homogeneous with the one customary for long range SSR (50 % probability of correct reception in a 12 seconds interval) the range obtained between FL 200 and FL 250 (typical for the experimental a/c) is of the order of 150 NM.

As it was to be expected, the coverage is strongly dependent on the MGS antenna siting. However, within MEDUP Programme time and budget constraints, the MGS location was in principle chosen for straightforward installation (availability of building, energy, communication lines, etc).

For future operational use the MGS antenna siting should be carefully evaluated, as it is usual for radar. MGS however has much simpler installation requirements in terms of space and energy.

**TIS-B** application (as well as other broadcast ground-to-air applications) is more influenced by the actual reliability in the Link performance because of its longer message structure and has proven effective at ranges between 100 and 150 NM. A reassessment of parameter settings and message structuring is likely to further improve the TIS-B range performance.

**CPDLC** point-to-point applications have proven more critical due to the complexity of the application protocols and partially due to lack of valid published standards for the same within the time frame of MEDUP. Moreover, the full availability of the relevant HW/SW packages has been delayed for different reasons and therefore only limited experiment has been feasible thus providing limited conclusions.

The results obtained by ENAV and AENA are not the same in all services/applications and in all cases and the summary given here is a joint result.

### 1.2.2-Demonstration Flights and Operators Acceptance

Test flights have been performed by the ENAV a/c and the AENA a/c for a total of about 85 hours of which part has been devoted to different technical verifications and some to pre-operational demonstration.

Most flights have been performed using shadow mode ATC Centres, manned with Controllers that monitored the experimentation in parallel with those on duty in the operational ACC. At the same time, on board of the equipped a/c during demonstration flights, it has been possible to visualize on the CDTI the information broadcast from ground or transmitted point-to-point.

Operators on ground and on board have expressed significant interest in the possible use of the MEDUP services enabled by an air to ground, ground to air data link. However, due to the limited time actually available for demonstration after all the necessary technical tuning, no deep pre-operational evaluation has been feasible.
1.3-Conclusions and future steps

1.3.1 -Conclusions

Section 5 below reports the experimentation outcome, safety and economical considerations, institutional issues, expansion to non ECAC States and exploitation plan.

Within the scope of the Executive Summary and after the synthesis of technical results given in Chapter 1.2 above, a short outline of the above issues is presented here.

The different applications/services are discussed with the following outcome:

• ADS-B is the most promising service, providing additional surveillance capability and with possible enhanced information which in turn enables better ATM functions
• TIS-B will be useful for cockpit situation awareness in mixed traffic (ADS-B equipped or not)
• CPDLC over VDLm4 should be further evaluated

With the functions enabled by the data link, flexibility of access and capacity of the Mediterranean airspace may be increased.

The relevant safety and economical considerations are covered in Chapter 5.2 Safety and economical issues and the institutional issues are discussed in Chapter 5.3 Institutional issues.

1.3.2- Possible future steps

With the conclusion of the almost four years Programme, it is important to consider possible future steps, stemming from the present MEDUP Programme and appropriately integrated in a wider international scenario.

Details on these possible steps will be given in Section 5.

Here it will be sufficient to highlight the basic lines of logical developments and/or complements to MEDUP, taking in due account the updated international expectancies for Data Link technology and for operational priorities (i.e. Package 1/Stream 1 Applications).

Moreover, the specific characteristics of Mediterranean area are appropriately considered within the overall Frame of Single European Sky (SES).

Several lines have been envisaged.

A first line is to complete any outstanding technical investigation about performances of VDL-4 Data Link by using equipment that are compliant to recently finalized ETSI European Norms that have been developed under the CEC Mandate M/318.

A second line is of more operational character, including deeper pre-operational experimentation (with more extensive operator involvement) and taking into account the frame of the Single European Sky policy, in terms of interoperability and seamless operations, although within the specific traffic pattern and structure of Mediterranean Area.

A third line may be oriented towards a comprehensive study for the completion of Data Link Infrastructure over the Mediterranean Area, especially involving the States of the southern and eastern Mediterranean shores, as same States show strong increase of tourist traffic and, in general, need infrastructure increase with economical restrictions. Appropriate consideration should be given to the role of complementary surveillance enabled by ADS-B and to the possible substitution of SSR Radars to be decommissioned in the future.

A fourth line should examine the feasibility of exploitation of MEDUP work in areas other than the Mediterranean one, but with similar air traffic problems and constraints.

A fifth line should comprise effective dissemination of actual results (including the different limitations
experienced in MEDUP Programme), with the involvement of a large spectrum of stakeholders and with appropriate co-ordination with other parallel Programmes.
Work Breakdown Structure of Sub-phases A1 and A2

Figure 2– Work Breakdown Structure of Sub-Phases A1 and A2
Figure 3– Work Breakdown Structure Phase B
2. Introduction

2.1-Purpose and Scope

The present document is the Final Report of ADS MEDUP Programme and has been prepared for consideration by all ATM stakeholders (CAAs, ATS providers, Airlines, Airports, professional associations, aircraft and ATM equipment manufacturers, etc).

It describes the starting point of ADS MEDUP and the activities performed since the beginning in March 2000 until the completion in December 2004.

It includes the evaluation of the background information and of the scenario as well as the discussion of requirements and specifications.

It provides information on the design, development, deployment of equipment and systems, both ground and airborne ones.

The results of the verification tests (on ground and in flight) and of the demonstration flights are reported together with the related analyses.

Conclusions are drawn from above results about the use of ADS-B and other related applications, all enabled by the datalink implemented in MEDUP (VDL-4) and cover several considerations:

- assessment of technical performances
- interest and comments by direct operators/users (pilots and controllers)
- institutional issues
- safety and economical considerations
- possible future steps

2.2-Final Report overview

The Document is composed by two volumes, the first one being the Final Report itself, the second one gathering many significant documents as Annexes. The first volume is subdivided into six Sections, which are briefly described hereafter. The dimension of each part is also indicated, possibly as a guide for the reader, according to the specific interests he may have.

Section 1 (7 pages) is the Executive Summary, providing a high level synthesis of the MEDUP Programme overall structure, of the activities performed, of the results obtained, of the conclusions and of the possible way ahead.

Section 2 (6 pages) is the present Introduction, giving also the list of referenced and applicable documents.

Section 3 (40 pages) describes, with detail as appropriate for the Final Report, the activities performed in preparation for the flight trials and namely:

- Chapter 3.1: Refinement and review of background information (traffic data, survey of studies, experimentation, standardization, description of scenario)
- Chapter 3.2: Requirements analysis and specifications, architecture description for ground and airborne environment
- Chapter 3.3: Infrastructure development and deployment, including the different ground and airborne infrastructures in the relevant sites across Mediterranean area. It reports, duly summarized, the results of technical tests performed on ground or with grounded equipment.

Section 4 (15 pages) is devoted to the Flight Trials, giving the summary of all MEDUP flights and providing
results and discussion of main performance issues (such as coverage range, interoperability, etc). Reference is made to the detailed Flight Reports, available in the MEDUP Web Site.

Section 5 (27 pages) on Final Considerations and Conclusions is subdivided, according to the Programme Management Plan, into five Chapters, namely:

- Chapter 5.1 on the actual results of the experimentation and to the possible operational interest.
- Chapter 5.2 gathers considerations on safety and economical aspects
- Chapter 5.3 covers institutional issues related to a wide area infrastructure
- Chapter 5.4 is devoted to the lines of possible expansion to non ECAC States
- Chapter 5.5 outlines a possible exploitation plan

Section 6 (3 pages) is a comprehensive Acronym List

The second volume (Section 7) gathers a small number of documents, referenced to in the Final Report that are enclosed for their relevance to some issues covered in the Final Report.

### 2.3 Documentation

#### 2.3.1-Referenced documents

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*This List covers all relevant Technical Notes prepared within MEDUP programme and is cross referenced to the text.*
| 11  | Operational Service Description (MEDUP-TEC-WP1.4-ENA-008-R1) 07-01-2003 |
| 17  | D22 - Specification of Ground Application Requirements (MEDUP-TEC-WP2.2-ENA-012-R2) 17-01-2003 |
| 18  | D22C - Data Link Server into MEDUP (MEDUP-TEC-WP2.2-AENA-001-R1) 17-01-2003 |
| 19  | D23A - MEDUP Airborne Station Requirements Specification (MEDUP-TEC-WP2.3-DFS-002-R2) 07-01-2003 |
| 20  | D23B - MEDUP Airborne CDU Requirements Specification (MEDUP-TEC-WP2.3-DFS-001-R2) 07-01-2003 |
| 21  | CDTI Technical Specifications (MEDUP-TEC-WP2.3-ENA-032-R2) 30-10-2002 |
| 22  | Integration Test Plan (MEDUP-TEC-WP3-ENA-033-D4) 31-03-2003 |
| 23  | Requirements Traceability and Compliance Matrix of MGS Supplied by Indra (MEDUP-TEC-WP3.2-AEN-002-D1) |
| 24  | MGS Requirements Traceability and Compliance Matrix of MGS supplied by AMS (MEDUP-TEC-WP3.2-AMS-020-D1) 30-04-2003 |
| 25  | NUP – ADS-MEDUP Ground Network Interconnection (MEDUP-TEC-WP3.2-DFS-001-D2) 17-01-2003 |
| 26  | Data analysis specifications (MEDUP-TEC-WP4.3-ENA-060-R1) 05-04-2004 |
| 27  | Economical consideration in the ADS- MEDUP programme (MEDUP-TEC-WP5.2-EEC-001-R1) 24-01-2005 |
| 28  | Safety consolidation for ADS MEDUP (MEDUP-TEC-WP5.3-ECC-002-R1) 24-01-2005 |
| 29  | Description of First Spanish MEDUP Flight (MEDUP-WP4.1.A-AENA-R1) 11-12-2003 |
| 30  | Description of the 22th January Test Flight (MEDUP-TEC-WP5-ENA-059-R1) 27-02-2004 |
2.3.2-Other applicable documents

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Concept of Use (Presented by the Secretariat)

E. WP 9 “INTEROPERABILITY” and “SEAMLESS” Considerations in air traffic management (Presented by the Secretariat)

F. WP 14 Comparative analysis of ADS-B data links (Presented by the Secretariat)

G. WP 71 Autonomous back-up systems to GNSS based on local infrastructure (Presented by Sweden)

H. WP 86 Initial ground surveillance and airborne surveillance applications enabled by ADS-B (Presented by EUROCONTROL on behalf of its Member States and those of ECAC)

I. WP 91 VHF data link Mode 4 considerations (Presented by the International Coordinating Council of Aerospace Industries Associations)

J. WP 166 Concerns with consideration for VDL Mode 4 to support ATC data communications (Presented by the United States)

K. IP 18 The UAT's role in the United States FAA ADS-B link decision (Presented by United States)

L. IP 44 Air-ground data link implementation in Europe: the Link 2000+ programme (Presented by the European Organisation for the Safety of Air Navigation — EUROCONTROL, on behalf of its Member States and those of ECAC)

Conference Reports

N. Report of Committee A to the Conference on Agenda Item 1 Introduction and assessment of a global air traffic management (ATM) operational concept
   General interest and specifically the following Recommendations.
   Recommendation 1-5 Interoperability and seamlessness.
   Recommendation 1-6 Endorsement of ADS-B concept of use and recommendations for further work.
   Recommendation 1-7 Ground and airborne ADS-B applications for global interoperability.
   Recommendation 1-16 Provisions related to ACAS.
   Section 1.2.4 on non relationship between ACAS and ADS-B.
   Appendix: Scenario Diagrams.

O. Report of Committee A to the Conference on Agenda Item 2 Safety and security in ATM
   General interest.

P. Report of Committee A to the Conference on Agenda Item 3 ATM performance targets for safety, efficiency and regularity and the role of RTSP in this respect
   General interest and specifically the following Recommendations.
   Recommendation 3-2 Standardization of minimum reporting requirements.

Q. Report of Committee A to the Conference on Agenda Item 4 Capacity-enhancement
## Measures

*General interest and specifically the following Recommendations.*

- Recommendation 4-3 Collaborative decision-making and global demand/capacity balancing.
- Recommendation 4-4 Investigation and analysis of the “Single European Sky” approach to global harmonization.
- Recommendation 4-5 Runway safety programmes.
- Recommendation 4-6 Capacity-enhancing procedures.

### Report of Committee B to the Conference on Agenda Item 5 ITU

*General interest*

### Report of Committee B to the Conference on Agenda Item 6 Aeronautical navigation issue

*General interest and specifically the following Recommendations.*

- Recommendation 6-6 Advanced GNSS Procedures design.
- Recommendation 6-7 Curved RNAV procedures.
- Recommendation 6-9 Support and participation in SBAS pre-operational implementation activities.
- Recommendation 6-10 Amendment to Annex 10, Vol I, Attachment B – Updating the strategy for introduction and application of non-visual aids to approach and landing.

### Report of Committee B to the Conference on Agenda Item 7 Aeronautical air-ground and air-air communications

*Overall interest, specific reference to Chapters 7.3 and 7.4 and more detailed in paragraphs 7.4.5 and 7.4.6. The following Recommendations are of outmost relevance.*

- Recommendation 7-1 Strategy for the near term introduction of ADS-B.
- Recommendation 7-2 Support of longer-term ADS-B requirements.
- Recommendation 7-3 Evolutionary approach for global interoperability of air-ground communications.
- Recommendation 7-5 Investigation of future technology alternatives for air-ground communications.

### European Telecommunications Standards Institute (ETSI)

- CEC Mandate M/318 on development of European Norms for VDL Mode 4

- Draft European Norms for Ground (EN 301 xxx), and Airborne Equipment (EN 302 xxx)

### RTCA Publications

**RTCA Minimum Aviation System Performance Standards (MASPS)**

- DO-289 MASPS for Aircraft Surveillance Applications (ASA) Vol 1 and 2
- DO-242/A MASPS for Automatic Dependent Surveillance – Broadcast (ADS-B)
- DO-286 MASPS for Traffic Information Service – Broadcast (TIS-B)
- DO-267 MASPS for Flight Information Service – Broadcast (FIS-B)
<table>
<thead>
<tr>
<th>FF</th>
<th><em>RTCA Safety and Performance Requirements Standards (SPRS)</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>GG</td>
<td>DO-290 SPRS for Air Traffic Data Link Service in Continental Airspace</td>
</tr>
<tr>
<td>HH</td>
<td><strong>ODIAC</strong> <em>Operational Requirements for air/ground cooperative air traffic services</em>, Edition 1.4, 19 May 2000</td>
</tr>
</tbody>
</table>

**Eurocontrol**

<table>
<thead>
<tr>
<th>II</th>
<th>Eurocontrol publication 2005-2009 ECIP/LCIP Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Objective SUR05: Implement ground-based surveillance in continental airspace and airports via ADS-B.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>JJ</th>
<th>Eurocontrol EATM ATM/CNS Consultancy Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AP/ACG/20/6 29.4.03</td>
</tr>
<tr>
<td></td>
<td>Incentives to encourage airline equipage: a practical example.</td>
</tr>
</tbody>
</table>
3. Activities performed in preparation for flight trials

3.1-WP1 Refinement and review of background information (including scenario and operational services description)

It should be appreciated that the review of background information has been done in several different steps and times, including a first synthesis in the Interim Report (IR)[3] at the end of Phase A2. In the present Final Report only significant, but short, syntheses are given as better explained in following Paragraphs for each item. All details may however be found in the deliverables of WP 1.1B; WP 1.2B and WP 1.3B.

3.1.1. WP1.1– Updating of traffic data, trends and analysis

First of all, it is reminded that the traffic pattern has been examined in different steps:

The first one was available from the SMAA/ADS-TEN Study and was referred to years 1996-1998
The second one has been developed at the beginning of MEDUP and included the information available for 1999 and 2000 [5].

The last one has been the updating in MEDUP Phase B [6] and has taken into consideration the effect of the Twin Towers tragedy.

For the scope of this Final Report it is sufficient to quote (with appropriate adaptations) the summary of the first two steps above (as prepared for the Interim Report [3]) and then add the considerations on the last years (2001 through 2003).

It is also reminded that the main purpose of traffic pattern examination was related to pinpoint:

a) the causes of any traffic problems in the Mediterranean area and

b) the main characteristics of the traffic texture and any difference with Europe Core area.

The WP 1.1 of Sub-phase A1, starting from the data in the /ADS-MED/TEN Study, provided an update of same data for the year 2000. It provides traffic data, trends and analysis for the Mediterranean Area covered by the responsibility of the four CAAs directly involved in ADS-MEDUP pre-operational experimentation (AENA, ENAV, MATS and HCAA).

Statistics and details are more focused on the effective needs of the following MEDUP activities i.e. commenting not only the quantity of the traffic but also the “type and texture”.

Looking at the various collected data, one is stricken by the fact of the widespread non-uniformity: The countries to the north have high traffic densities and good infrastructures; the ones to the south & east have minimal infrastructures and low traffic densities (one could also cite the lower GNPs and political instability).

Some countries belong to ECAC; others also to Eurocontrol; still others to the European Union as well; and finally some to none of the aforementioned organizations. So, it is a transitional airspace, covering large sea areas, with medium density traffic, and with dramatic differences in CNS-Equipment coverage (very good in the northern Mediterranean – very poor in the southern).

For the next decade, the growth in the Mediterranean traffic (according to Eurocontrol statistical analyses) was predicted to be considerably higher compared to the rest of Europe. Especially, the routes originating from Northern Europe (West & East) towards South Asia & Pacific are of the highest demand; these routes are already in third place (in terms of demand) behind only the transatlantic and transpacific routes.
Traffic over the Mediterranean has a “crossing” pattern since the main flows are both from North to South (Europe-Africa) and from East to West – and vice versa. In addition, due to the prevailing political conditions, there is a great necessity to allow for a flexible airspace for both military and civil operations.

One must note that, although the traffic in the Mediterranean can be classified as “medium” on the average, there is a bothersome number of very congested Way-Points (e.g. ELB, LUNK, ISTER, PNZ, ALG, LATAN, MIL). At such major intersections (quite a few due to the “crossing” traffic pattern) the traffic is so “heavy” that, despite double (and sometimes triple or quadruple) radar coverage, bottlenecks, delays and the like are commonplace.

In addition, the insufficient infrastructure of the southern Mediterranean countries and (despite the extensive infrastructure of the northern Mediterranean countries) a number of all-disturbing coverage holes in surveillance contribute even more to such “unavoidable” bottlenecks and delays (and increased costs) – especially in the highly demanded routes from Northwestern Europe to South Asia & Pacific. Similar delays and extra costs plague the traffic between Europe and Africa.

Similarly, the lack of infrastructure in the Balkans (except Greece) leads to the hindrance of the connection between East Europe and Africa & Middle East (or farther on to South Asia & Pacific).

Furthermore, there exists the problem of aircraft with unknown flight plans traveling from South to North and crossing the boundaries between the North African FIRs and the European FIRs. This occurs repeatedly leading to an (unnecessary) increase of controller workload.

Finally, another element of non-uniformity is the “mixed” composition of the fleet crossing the Mediterranean – with the fleet of the southern Mediterranean countries being considerably older.

**So much for the situation before 11 September 2001.**

For years 2001 and 2002, interesting observations can be made by examining the traffic evolution within the MEDUP area; and by comparing the traffic situation (past-present-future) of the MEDUP area and the average of other European areas (Euro98).

Based mainly on STATFOR data and national statistics available from the different MEDUP Partners individually, one can highlight the following predominant elements:

- Even before the Twin Towers tragedy, predictions regarding the traffic growth in Europe had been proven overoptimistic. Looking at the ambitious predictions of 1998 and to the statistics of the first part of 2001 one would be inclined to assume that air traffic was probably already (previous to 11September 2001) entangled in a growth crisis.

- In the 3-year period leading to 2000, traffic growth was much faster in the MEDUP area than in the Euro98 area (incorporating all European States). Specifically, the growth rate in the former was approx. 21.5% as compared to 9.6% in the latter.

- After the events of 11 September 2001, the dip in traffic evolution was similar (percentagewise) for both MEDUP & Euro98.

- after the nadir reached following 11 September 2001 the recovery has been much faster in the MEDUP area than the Euro98 area. Thus, during the last 4 months of year 2002, the traffic growth rate was 5% in MEDUP area (half of what it was in the “boom period” of the last 4 months of 2000) while it was “only” 3.6% in Euro98-area.
3.1.2. WP1.2– Survey of existing studies, experimentation and standardization activities

3.1.2.1. Studies and experimentation

a) The Eurocontrol ADS Programme constituted the overall framework for ADS evaluation and deployment in Europe and was closely followed during the ADS MEDUP development to assure appropriate insertion of a more general European picture, to avoid duplication of efforts and to provide additional information from ADS MEDUP as appropriate.

b) The Study for transition to new generation ATC systems in the Russian Federation is an example of CNS/ATM deployment, which takes into full consideration the special conditions of large parts of the Russian airspace. Concerned Aeronautical Authorities (such as FAAS, GOSNI, AERONAVIGATSA, GOSNIAS) have been involved significantly contributing to the realisation of this study providing valuable information and support. The study points-out the needs for Russian Federation Airspace modernisation starting from the opening of new international air routes. Consequently, implementation of updated infrastructure and on board devices adopting latest state of the art technologies (such as ADS - VDL mode 4) is considered.

Among the all analysed project, three of them have been selected as considered to have the most advantageous return of investment.

- Trans-Asiatic routes
- Trans-Polar routes
- Far East routes

It was analysed each one of the above family’s routes evaluating the feasibility of the project are the following:

- Improve strategic Air traffic planning and co-operation with Western Europe and Asia by implementing an air traffic flow management for Commonwealth states.
- Develop an efficient and effective maintenance and support system to ensure a high degree of system availability.

Among the experimental activities, Faraway 1, Faraway 2, NEAN-NEAP-NUP were given special attention as they utilise the VDL-4 family (starting with STDMA and ending with VDL Mode 4).

c) The main result of FARAWAY II was the implementation of a pre-operational real-time CNS/ATM demonstrator that exploits live data and is operated by controllers and pilots in “shadow mode”. The FARAWAY demonstrator has been validated in compliance with the CONVERGE methodology used within the Transport Sector of Telematics Applications in EC Fourth Framework Programme. During the trials, all the relevant data have been 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 technical and user acceptance aspects. The FARAWAY-projects recorded very good results from testing of prototype VDL Mode 4 equipment for ADS-B, TIS-B, FIS-B, GNSS Augmentation and point-to-point communications. Three ACC’s (Brindisi, Padua and Rome) were equipped with ground stations and three Alitalia MD-80’s and one Beech KingAir were equipped with avionics.

d) The NEAN/NEAP projects (North European ADS-B Network) was operating a large number of ADS-B ground stations and aircraft in more than 10 different countries throughout Europe. The baseline for NUP is the use of ADS-B based applications and services and data broadcast technology. The project is managed according to a collaborative project model.

The main objectives of the NEAN Update Programme were to:
• develop an operational concept for ADS-B based ATM and;
• identify, investigate and develop candidate ADS-B and CNS applications with maximum benefits\(^1\) for the parties and;
• involve key industries in the work and;
• provide a network management concept for operational use through the creation of a redundant network management function and;
• upgrade to VDL Mode 4 compatible equipment and;
• investigate the conditions for and plan an extension of NEAN into other areas of Europe and;
• embed a DGNSS Augmentation Service for gate-to-gate operations and;
• develop provisions for an ATN sub-network in NEAN and;
• develop network architecture in support of enhanced surveillance for ATC and;
• collaborative planning between CFMU, airlines, airports and ATC and;
• increase the number of aircraft in the network and;
• to co-ordinate with other related projects

The update programme enables states in Northern Europe to begin pre-operational use of the network.

e) Capstone is a large-scale experimentation of ADS-B in a specific scenario, namely the Alaskan Behlen region, where any infrastructure is only sparsely available. A large number of general aviation a/c have been equipped with avionics for which FAA contributed with some 25,000 US$ per aircraft.

f) The TACIS Southern Ring Air Route Programme joins together GPS navigation, ADS-B and use of data link to improve the airspace capacity. The project was demonstrating the benefits of ADS-B on a number of Russian produced aircraft and helicopters. Mongolia is currently installing VDL Mode 4 ground and airborne equipment.

g) Among the Programmes related to ADS-B, Safe Flight 21 is of interest as it joined USA (FAA) and Europe in the examination of different topics related to ADS-B and Data Link. The project was completed in March 2001 and provided indepth analysis of the technical characteristics of the three candidate ADS-B technologies (VDL Mode 4, 1090 ES and UAT). One conclusion was that none of the three candidate technologies met all evaluation criterias. The work unveiled serious limitations for 1090 ES and it was recommended that a combination of VDL Mode 4 and 1090ES would be an interesting solution. Further modification and refinement of the then existing draft standards for VDL Mode 4 has resulted in significant improvements of the VDL Mode 4 performance, and extensive subsequent simulations conducted by Eurocontrol shows that VDL Mode 4 will meet all the operational requirements prepared by FAA for Safe Flight 21.

h) MA-AFAS is together with MFF examples of Programmes of wide interest for medium term applications in which ADS-B and Data Link are essential enablers. MA-AFAS has been completed and a separate report is available. MFF will be completed in November 2005 and is reported separately.

\(^1\) Benefits in terms of increased capacity and safety
3.1.2.2. Standardization activities

Regarding standards available on ADS and, in particular, on VDL Mode 4, at the beginning of the project the Consortium performed a survey of existing documents and work already performed at different standardisation organizations.

After a follow up of the available standards during the course of the project, the survey was last reviewed at mid 2004, which might possibly cause that at publication date of this Final Report the survey will not reflect some minor changes in ICAO, ETSI, EUROCAE, Eurocontrol, etc., published documentation.

The survey performed within MEDUP on ADS related standards is summarized in the following tables:

<table>
<thead>
<tr>
<th>Standard</th>
<th>Organization / Standardisation body</th>
<th>Document / Status</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICAO Manual of ATS Data Link Applications</td>
<td>ICAO (ADSP)</td>
<td>Doc 9694-AN/955 (First edition, 1999)</td>
<td>One chapter on ADS and another one on ADS-B. (Part on ADS-B is dated 1996 and is out of date).</td>
</tr>
<tr>
<td>ADS-B MASPS</td>
<td>RTCA (SC-186, WG6)</td>
<td>RTCA/DO-242A (April 2002)</td>
<td>Specially designed for USA (it does not include special European needs/features). Revision A approved by SC-186 in April 2002. WG6 is coordinating with Eurocontrol and EUROCAE in an attempt to have the next revision as a joint US/European document.</td>
</tr>
<tr>
<td>ADS-B MASPS</td>
<td>EUROCAE</td>
<td>Document has already been initiated</td>
<td>Document has already been started. If agreement is reached it might be published jointly with there viewed edition, DO-242A, of RTCA MASPS.</td>
</tr>
<tr>
<td>VDL – Mode 4 SARPs</td>
<td>ICAO (AMCP)</td>
<td>Published Nov. 2001 October 2002</td>
<td>Already included in Annex 10, Volume III, Part I, Chapter 6 (October 2002)</td>
</tr>
<tr>
<td>Mode S extended squitter SARPs</td>
<td>ICAO (SICASP)</td>
<td>1998</td>
<td>Already included in the Annex 10 to the Convention on International Civil Aviation Volume IV.</td>
</tr>
<tr>
<td>UAT SARPs</td>
<td>ICAO (AMCP)</td>
<td>V. 1.0 Draft SARPs (October 2002)</td>
<td>Original Draft: September 2002, v 0.1 UAT Subworking Group of WGC currently conducting further review and development of the Draft SARPs, transmitted to the GNSSP for review of the RF compatibility aspects.</td>
</tr>
<tr>
<td>Description</td>
<td>Organization</td>
<td>Date</td>
<td>Notes</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------</td>
<td>--------------</td>
<td>-----------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>VDL Mode 4 Implementation Manual</td>
<td>ICAO (AMCP)</td>
<td>October 2002</td>
<td>Contains all the approved changes up to and including WGM5, excluding all text related to the new DLS Amendment Proposal AMCP/8 (Feb. 2003): amendments to Part II. It is expected to be published during the second quarter of 2003.</td>
</tr>
<tr>
<td>MOPS for Airborne ADS Equipment</td>
<td>RTCA (SC-170)</td>
<td>RTCA/DO-212 (Oct, 1992)</td>
<td>The Document deals with ADS-C. It specifies the OSI protocols and services needed to service the ADS application process, as well as the data transfer requirements.</td>
</tr>
<tr>
<td>MOPS for VDL Mode 4 Aircraft Transceiver for ADS-B</td>
<td>EUROCAE (WG-51, SG-2)</td>
<td>ED-108 Issued in July 2001 as Interim MOPS</td>
<td>It deals with VDL Mode 4 (STDMA). The functional requirements which are specified in ED-108 relate solely to the ADS-B application and do not cover ATN interfaces. Publication pending on SARPs publication.</td>
</tr>
<tr>
<td>MOPS for 1090 MHz ADS-B equipment</td>
<td>EUROCAE (WG-51, SG-1)</td>
<td>RTCA/DO-260A (vers.5B) EUROCAE/ED-102 (January 2003)</td>
<td>It deals with Extended squitter technique for ADS-B and TIS-B. WG 3 (RTCA) recently completed RTCA SC-186 plenary approval on January 30, 2003 for DO-260A Scheduled for review by the RTCA Program Management Committee (PMC) on April 10, 2003. DO-260A includes many changes from the DO-260 Joint RTCA/EUROCAE document.</td>
</tr>
<tr>
<td>MOPS for UAT</td>
<td>RTCA/DO-282 (SC186 WG5)</td>
<td>Issued August 2002</td>
<td>It deals with UAT technique for ADS-B and basic ground uplink capabilities. Potential modification to section</td>
</tr>
<tr>
<td>ETSI VDL4 Standards</td>
<td>ETSI</td>
<td>Draft European Norm Draft ETSI EN 301 842-1 V1.1.1 (May 2001) Draft ETSI EN 301 842-2 V1.1.1 (June 2002)</td>
<td>2.2.2.4 will be considered, as well as some changes, most likely editorial, will be proposed in next WG5 meeting, April 2003. It deals with VDL4 from a pure communications point of view. Multi-part deliverable covering the VHF air-ground Data-Link VDL mode 4 radio equipment; Technical characteristics and methods of measurement for ground-based equipment. Second part submitted for the Vote phase of the ETSI standards Two-steps Approval Procedure. Mandate released for the production of Part 3 and part 4.</td>
</tr>
<tr>
<td>ATN SARPs (also called CNS-ATM/1 SARPs)</td>
<td>ICAO (ATNP)</td>
<td>Published</td>
<td>Already included in the Annex 10 to the to the Convention on International Civil Aviation Volume III, part 1.</td>
</tr>
<tr>
<td>Manual of technical provisions for the ATN.</td>
<td>ICAO</td>
<td>Doc. 9705-AN/956 Ed. 3.0. (August 2001)</td>
<td>It is the reference document for the ATN SARPs of ICAO.</td>
</tr>
<tr>
<td>AMSS SARPs</td>
<td>ICAO (AMCP)</td>
<td>Published.</td>
<td>Amendment proposals, agreed by WG-M, made to the AMSS SARPs in Annex 10, Volume III, Part I, Chapter 4, in AMCP/8 (Feb.2003)</td>
</tr>
<tr>
<td>HFDL SARPs</td>
<td>ICAO (AMCP)</td>
<td>Published</td>
<td>Already included in the Annex 10 to the to the Convention on International Civil Aviation Volume III, part 1. Some amendments agreed to these SARPs in AMCP/8 (Feb. 2003)</td>
</tr>
<tr>
<td>VDL Mode 1 SARPs</td>
<td>ICAO (AMCP)</td>
<td>Published</td>
<td>Already included in the Annex 10 to the to the Convention on International Civil Aviation Volume III, part 1.</td>
</tr>
<tr>
<td>VDL Mode 2 SARPs</td>
<td>ICAO (AMCP)</td>
<td>Published</td>
<td>Already included in the Annex 10 to the to the Convention on International Civil Aviation Volume III, part 1. Amendment proposals to SARPs. AMCP/8 (Feb.2003). Some of the proposals were accepted and some are still pending. The rest of the proposals were rejected (WG M).</td>
</tr>
<tr>
<td>VDL Mode 3 SARPs</td>
<td>ICAO (AMCP)</td>
<td>Validated by AMCP (AMCP/7 March 2000)</td>
<td>Recommended for publication by AMCP.</td>
</tr>
<tr>
<td>NGSS SARPs</td>
<td>ICAO (AMCP)</td>
<td>Not published yet</td>
<td>Under elaboration Maybe merged with AMSS SARPs in the future (AMCP WGM/6).</td>
</tr>
<tr>
<td>Manual on Mode S specific services</td>
<td>ICAO</td>
<td>Doc. 9688. First edition. (1977)</td>
<td>All of the technical requirements of</td>
</tr>
<tr>
<td>Document</td>
<td>Prepared by</td>
<td>Publication Date</td>
<td>Status/Content</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
<td>------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>VDL Mode 4 SARPs</td>
<td>ICAO-VDL Mode 4 Core SARPs</td>
<td>November 2001</td>
<td>Approved</td>
</tr>
<tr>
<td>VDL Mode 4 SARPs – Technical Manual</td>
<td>ICAO-VDL Mode 4 Technical Manual</td>
<td>Expected 1 Q 2003</td>
<td>Approved by ICAO AMCP; February 2003</td>
</tr>
<tr>
<td>Minimum Operational Performance Specifications (MOPS) for Airborne Equipment</td>
<td>EUROCAE ED-108</td>
<td>July 2001</td>
<td>Called Interim awaiting update according to ICAO SARPs and CEC Mandate M/318.</td>
</tr>
<tr>
<td>VDL Mode 4 European Norms (EN) for Ground Equipment</td>
<td>ETSI EN 301 842-1, Part 1 and ETSI EN 301 842-2, Part 2</td>
<td>February 2003</td>
<td>Approved</td>
</tr>
</tbody>
</table>

There is one section (chapter 10) devoted to “Extended squitter, system concept and applications”.

Although it is not an official standard, it is being used in practice. Before ICAO produced the CNS/ATM standard, industry started to develop their own specification for a more immediate use. Boeing has already equipped some of their aircraft with ARINC standard.

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Table 1 - survey performed within MEDUP on ADS related standards

Regarding the standards on the particular technology used in MEDUP (VDL mode 4), the situation is reflected in the following table:
## Table 2 - Documents and Standards regarding VDL-4

<table>
<thead>
<tr>
<th>VDL Mode 4</th>
<th>European Norms (EN) for Ground Equipment</th>
<th>ETSI EN 301 842-3, Part 3</th>
<th>Expected October 2003</th>
<th>Covers additional broadcast applications; TIS-B, FIS-B and GRAS</th>
<th>Update work as in CEC Mandate M 318 starting 28 February 2003; Completed late 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDL Mode 4; Ground station co-ordination, Networks</td>
<td>NUP II, MEDUP/MFF (and Eurocontrol)</td>
<td>Completed 2001/2002</td>
<td>Implementation 2003-2004</td>
<td>NUP II incl. most North European CAA’s, Lufthansa and SAS; MEDUP/ MFF incl. North Mediterranean states, LFV, NATS and NLR.</td>
<td></td>
</tr>
</tbody>
</table>

### 3.1.3. WP1.3- MEDUP scenario description (OSED)

This paragraph provides a synthesis of the work done in WP 1.3 B for the definition of operational scenarios in which the MEDUP experimentations take place. The full details, to be found in WP 1.3 B [10], describe the routes to be used, the selected airspace spanning from Madrid to Athens, the expected composition of fleet/equipage and of airspace operators.

The organization, planning, and staffing for Demonstration flights and the criteria to be used for evaluation is reported in Section 4 below.

#### 3.1.3.1. Generals

The ADS-MEDUP OSED presents the characteristics of the ATM environment where the flight experiments will be conducted and relevant operational services supported by the MEDUP system and other existing infrastructures/systems.

A definition for Operational Service is given, quoting from the ICAO Manual of ATS Data Link Applications, First Edition, 1999 [A]:

A data link service is a set of ATM-related transactions, both system supported and manual, within a data link application, which have a clearly defined operational goal. Each data link application service is a description of its recommended use from an operational point of view”.

ADS-MEDUP provides a set of interacting operational services, to be exploited during all phases of flight, supporting new ATM concepts like collaborative decision-making and limited redistribution of tasks between ATC controller and aircrews.

Since an operational service can exploit other ones, a hierarchy based on a one-to-many relationship exists in the set of supported services. The interactions among the services are clearly stated in the full WP1.3 B Report [10].

The main reference document for ADS-MEDUP operational services is represented by ODIAC Operational Requirements for air/ground cooperative air traffic services, Edition 1.4, 19 May 2000.
3.1.3.2. Routes description and selected airspace

A graphical description of MEDUP routes is given hereafter, evidencing also the airspaces (FIRs) involved.

Figure 4 - Route configuration

Again, details about Waypoints, etc are given in WP 1.3 B [10].

3.1.3.3. Fleet composition and equipage

In WP1.3 B [10] there is a detailed examination of fleet composition and equipage actually not updated. Therefore it is preferable to refer to the considerations of paragraphs 5.2.2.2-Fleet Composition and 5.2.2.4-Equipage below and which are quoted here for convenience being referred to MFF document.

Quote:

The MFF Programme has carried out a detailed analysis of the expected distribution of aircraft types in the MFF area in 2010. This has considered the aircraft types currently using the MFF airspace and has made some assumptions about how those aircraft types might be substituted in 2010, in whole or in part, with more modern aircraft.

For these preliminary considerations it will be assumed that the mix of aircraft types is currently similar in both the MEDUP and MFF areas and hence that the MFF analysis provides a good estimate of the aircraft types that will use the MEDUP airspace in 2010.

The following chart is extracted from. It covers the 20 most common aircraft types, which account for 80% of the traffic.
The fleet composition analysis allows identifying the number of new aircraft that will be introduced after 2010. If it can be assumed that all new aircraft will be supplied with the necessary technology to support the MFF applications after some year from 2010, a minimum value may be found for the percentage of aircraft that will be equipped in 2010-2015. Any retrofit on existing aircraft (with adequate residual life) will increment that minimum value.

Unquote

It is recalled that for ADS MEDUP experimentation the aircraft equipped have installed on board the following equipment:

- VDL-Mode 4 transponder, complete with its own GPS receiver and relevant antennas.
- CDNU (Cockpit Display Navigation Unit), also called CDTI (Cockpit Display of Traffic Information), including navigation display, input output device for the pilot and Data-Link communication management system.
- Interface Unit with aircraft systems

The CDNU software will allow the applications foreseen for the experimentation.

3.1.4. WP1.4- Operational Services description

The MEDUP infrastructure will support a number of ATS operational services (interchangeably called applications) either common ones to all participant countries or specific ones to some country.

A summary of all such services (or applications) is contained in the following table:

<table>
<thead>
<tr>
<th>Service / Application</th>
<th>Overview</th>
<th>Operators involved</th>
<th>Items involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATC Communications Management</td>
<td>When a flight is about to be transferred from one Sector/ATSUnit to another, the Aircrew is instructed to change to the voice channel of the next Sector/ATSUnit which is to take control of the flight; the ACM provides</td>
<td>Aircrew and Controllers</td>
<td>ATC DataLink</td>
</tr>
</tbody>
</table>
**ACM**

Automated assistance to the Aircrew and to the "current" & "next" Controllers for conducting this transfer of ATC communications; the ACM encompasses the transfer of all Controller/Aircrew communications, both the voice channel and the new data communications channel used to accomplish this ACM.

**ATC Clearance-and-information (ACL)**

The ACL describes Aircraft/Controlling ATSUnit A/G data communication message exchange and procedures for operations within the European region for:
- Aircrew’s reports and clearance requests,
- Controllers’ delivery of clearances/instructions/notifications-to-aircraft,
- Support and system messages; the ACL description also states the rules for the combination of voice & data link communications and requirements & procedures for abnormal cases.

**Controller Access Parameters (CAPs)**

Aims at enhancing the ATC surveillance and the availability of a/c parameters to the Controllers by extracting & downlinking data from the airborne system.

**FLight Plan ConsistencY (FLIPCY)**

Permits the GND system to check that flight data in the FDPS correspond to actual flight plan data from the a/c; it should take place automatically at logon.

**Datalink Operational Terminal Info. Service (D-OTIS)**

Provides automated assistance in requesting and delivering compiled meteorological and operational flight information derived from ATIS, METAR and NOTAMs/SNOWTAMs, specifically relevant to the departure, approach and landing flight phases.

**Data Link Logon (DLL)**

Encompasses all data link exchanges required to enable (all) the other applications.

**ADS-B**

Allows the a/c to continuously broadcast to air and ground users (x,y,z,t,id,TCP,etc.)-data thus enhancing surveillance.

**Ground-based Regional Augmentation System (GRAS)**

Provides (by broadcasting) GNSS augmentation data to mobiles in all user groups (e.g. ground moving vehicles, aircraft).

**Traffic Info. Service – Broadcast (TIS-B)**

Through this service radar information available on the ground surveillance system is broadcast, allowing the aircrews of aircraft equipped with a CDTI to have an air situation picture. There are two options of TIS-B: full picture, in which all surveillance information available on ground is broadcast; and gap filler in which only radar information of aircraft non ADS-B equipped is broadcast. In ADS MEDUP, the gap filler option has been used.
ATS Interfacility Data Communication (AIDC) | Allows the exchange of information among ATS Units in support of critical ATC functions including notification of flight approaching the FIR-boundary, coordination of boundary-crossing conditions, and transfer of control. | Controllers G/G communication

| Table 3– Summary of Applications/Services |

The above services/applications are common to all installation sites except the CAP service and the FLIPCY service, which will be provided only at Italian and Spanish sites.

The services/applications tabulated above, enabled in the case of the ADS-MEDUP Project by VDL-4 technology, would provide (when implemented) significant improvements in the overall Air Traffic Management in the Mediterranean airspace in terms of capacity, flexibility, cost effectiveness, and safety.

### 3.2-WP2 Requirements analysis and specifications

This chapter describes the logical path from objectives of the Programme through relevant requirements, analysis of same and finally specifications for the different parts of the systems.

#### 3.2.1-WP2.1- Core Platform

The MEDUP core platform is represented by the ATM communication infrastructure, and its network elements (MEDUP Ground Stations – MGS) that are linked together in order to guarantee the seamless distribution of broadcast (ADSB, TISB, FISB) and point-to-point CPDLC related messages.

The requirements for the Core Platform were specified in the following three main documents:

- MEDUP System Architecture Document [12], which describes the architecture, the components, the services and the core protocols of the MEDUP network
- MEDUP Ground Station Specification [13], which provides the requirements for the VDL Mode 4 ground station compatible also with the NUP requirements
- ADS-B Router Requirements Specification [14], which provides the requirements for the ADS-B Router software, the main component that guarantee message distribution throughout the network and provide services to the external systems
- Ground Network Interface Control Document [15], which described the protocols to be used by external systems that use the MEDUP network to manage broadcast and point to point messages
- MEDUP Internetwork and Dialogue Service ICD [16], which describe a higher-level ATN-oriented software interface, specifically used to exchange ATN application messages (i.e. CM, CPDLC and AIDC messages).

#### 3.2.2-WP2.2- Applications

The list of Data Link Applications/Services considered by MEDUP has been given in paragraph 3.1.4 above together with the relevant description.

The requirements for the mentioned applications were mainly drawn from available and widely accepted documentation (although not yet fully standardized).

The main sources for broadcast applications come from the documentation produced by the NUP program, in order to pursue a basic interoperability between the two programs.

The requirements for CPDLC are mainly captured from the document “Operational Requirements for
Air/Ground Cooperative Air Traffic Services” (ACG-ORD-01, Edition 1.0, 2/4/2001). That document contains Operational Requirements for Air Traffic Management (ATM) Air-Ground Data Communications Services produced by the Operational Development of Integrated surveillance and Air/ground Data Communications Sub-Group (ODIAC-SG). Those operational requirements represent consolidated European operational requirements and provide input to the ICAO Operational data Link Panel (OPLINKP).

MEDUP consortium has developed specifications for the applications and/or services to be implemented in the project [19]. Service specifications developed within MEDUP are mainly functional, whereas the implementation issues are left open to each system.

The following table summarises main specifications set for each service/application:

<table>
<thead>
<tr>
<th>“MEDUP” Datalink Application/Service</th>
<th>Requirements outline</th>
</tr>
</thead>
</table>
| **ADS-B**                            | • Each new ADS-B report received on ground, shall be provided to the Surveillance Processing Ground System which shall be able to generate fused tracks using both ADS and radar data sources.  
• The tracks shall be visualised on the HMI with a special symbol in order to differentiate them from the radar-only system tracks.  
• ADS-B report containing the air vector block, indicated air speed, heading and vertical rate shall be available via CAP.  
• ADS-B reports shall be in ASTERIX Cat. 21 format. |
| **TIS-B** (Traffic Information Service – Broadcast) | For the defined area of interest TIS-B shall:  
• Receive the system tracks (call-sign, SSR code, $\lambda$, $\varphi$, GND speed1, altitude, climb/descend indicator, track angle) provided by Surveillance Data Processor.  
• Extract the required information to be broadcast from the system track.  
• Display an error message in case the connection to the MEDUP communication segment is not working properly or a received system track is corrupted. |
| **GRAS**  
**Ground Regional Augmentation Service** | GRAS shall make use of three different service levels:  
- **GRAS service level 1** (integrity information): Intended for en-route operations.  
- **GRAS service level 2** (standard augmentation i.e. integrity and improved accuracy): Intended for En-Route, Terminal Area, Initial/Intermediate/Non-Precision Approach, Departure and Surface operations; enabling applications based on ADS-B such as ASAS, station keeping, and A-SMGCS (monitoring purposes).  
- **GRAS service level 3** (advanced augmentation i.e. integrity, improved accuracy and Flight-level Allocation System data): Intended for approach and landing with vertical guidance.  
- **GRAS service level 4** (“more” advanced augmentation i.e. integrity, improved accuracy and surface guidance): Intended for future critical operations and applications such as A-SMGCS (guidance purposes). |
| **D-OTIS**  
**Data Link Operational Terminal Information Service** | The broadcast ATIS service shall be implemented. ATIS shall:  
- Send in uplink the current ATIS information.  
- Provide an HMI that allows the User to send an ATIS message manually. |
| **DLL**  
**Data Link Logon** | The DLL service will be implemented through the DLIC (Data-Link Initiation Capability) application. It should encompass the following functions:  
- Logon (Request and Response).  
- Update (Request and Response).  
- Forwarding. |
| **ACL**  
**ATC Clearances** | The application shall be in charge to allow the user to start a CPDLC connection. The CPDLC application shall be able to manage a subset of the ICAO messages set and handle reception of incorrect or invalid messages. |
| **ACM**  
**ATC Communication Management** | The ACM Service shall provide the transfer of CPDLC data communications from one controller to the other. It contains exclusively the A/G data link exchanges between an Aircraft, its T-ATSUnit (the transferring ATSUnit) and its R-ATSUnit (the next ATSUnit to take control of the flight). The ACM service shall be able to operate without G/G data communications and shall enforce the operational principle that there is only one controlling authority. The ACM Service shall support the following configurations:  
1. Both the T-ATSUnit and the R-ATSUnit are equipped for A/G data link.  
2. Only the T-ATSUnit is equipped for A/G data link.  
3. Only the R-ATSUnit is equipped for A/G data link.  
4. Transfers within one ATSUnit. |
The Ground System shall perform the FLIPCY service for aircraft that are expected to enter the ATSUnit’s area of responsibility:

- ATSUnit shall send to the aircraft via data link the request for the 2D route activated in the aircraft FMS. If a valid waypoint sequence is received, the FLIPCY shall request the FDP for the stored flight plan. The flight plan received from the FDP shall be compared with the one received from the aircraft through the CPDL. 
- A warning message shall be sent to the FDP, informing whether the flight plans differ or not. 
- Error messages shall be displayed in case if no answer is received from the aircraft.

As a result of the User’s request, the HMI shall display the following information:

- Indicated Air Speed;
- Magnetic Heading;
- Vertical Rate (of the air vector block).

Warnings shall be displayed in case the requested information is not available or a not valid value is received.

The AIDC messages shall be generated and sent in time ordered sequence. An ATSUnit receiving a message shall acknowledge the receipt to the transmitting ATSUnit. Non-receipt of the Application Response within the required time will result in exception processing.

**Table 4 - Outline of Requirements for the “MEDUP” Applications**

All above mentioned “MEDUP” services with the exception of GRAS shall be implemented in the Data Link Server.

### 3.2.3-WP2.3- Airborne Platform

This Sub-WP specified in two different documents the MEDUP Airborne Platform (MAP), which consists of the MEDUP VDL Mode 4 Airborne Station [19] and the Cockpit Display and Navigation Unit (CDNU) [20].

#### 3.2.3.1- The MEDUP VDL-4 Airborne Station

The MEDUP VDL-4 Airborne Station is a transponder which is using VDL-4 as a data link to transmit and receive the various Communication, Navigation and Surveillance data. The objective of the airborne system is to broadcast ADS-B messages, to receive the broadcasts from the MEDUP ground stations and to enable the communication between the MEDUP CDNU and the MEDUP Ground System.

Within the MEDUP programme VDL-4 airborne transceivers were procured from 2 different manufacturers. It was one of the objectives of the programme to demonstrate the interoperability between these different transceiver types and the transceiver types used in other programmes (especially the NUP programme).
3.2.3.2-The Cockpit Display and Navigation Unit (CDNU)

The Cockpit Display and Navigation Unit (CDNU) is an onboard display unit that has the task to provide the crew with all the information concerning outer environment in which the aircraft is moving. The CDNU is running the software applications that cooperate in the CNS/ATM scenario. In the relevant document is a detailed description of the requirement specifications for the MEDUP Airborne CDNU necessary to support the MEDUP operational services: ADS-B, TIS-B, GRAS, D-OTIS, DLL, ACL, ACM and AIDC (common operational services provided at all MEDUP sites); FLIPCY, CAP (specific operational services provided at the Italian and Spanish sites only); CPDLC (complete set of messages for all relevant applications). Excepting the AIDC application, which is a G/G application, all applications require airborne functions (described in the relevant document). All system requirements are based on service descriptions developed by the Eurocontrol ODIAC Task Force.

In order to optimize the benefits from the performance of European Commission funded programmes, it was decided to harmonize the development of the MEDUP CDNU with the foreseen development of an ASAS Cockpit Display necessary for the MFF programme in a later stage. The common development is called “CDTI/ASAS Unit” with the industrial product name “CDTI-2500”.

The “CDTI/ASAS Unit” required by the two experimental programmes is mainly requested to perform a graphical visualisation of current aircraft own position and surrounding traffic positions received through ADS-B and TIS-B applications. Within the MFF programme, enhanced ASAS capabilities are requested, and traffic visualisation should be integrated with visual aids supporting ASAS operations, both in managed and in Free Flight airspace. The “CDTI/ASAS Unit” was based on basic COTS product upgraded to fulfil ADS-MEDUP and basic MFF operational requirements and ready to accept external software applications developed within the MFF programme activities.
Figure 7 - MEDUP VDL-4 Airborne Platform
3.3-WP3 Infrastructure development and deployment

3.3.1-Summary

The following picture shows the overall deployed infrastructure. Elements of the ground system are:

- MGS (MEDUP Ground Station)
- ATC Shadow Mode system
- ISDN/IP routers

The a/c equipped with VDL-4 Transponder and CDTI (see paragraphs 3.3.2.3-Airborne System: Italian aircraft and 3.3.3.2-Airborne System - Spanish Aircraft, below) are integral part of the “infrastructure” and provide the testing means for the air-ground and ground-air applications as planned in MEDUP.

It is also recalled that the MEDUP ground infrastructure supports the MFF Flight Trials.
The following table summarises the exact configuration deployed in each MEDUP site.

<table>
<thead>
<tr>
<th>Site</th>
<th>State</th>
<th>Configuration</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roma (ENAV Experimental Centre and Ciampino ACC)</td>
<td>Italy</td>
<td>MGS and shadow mode ATC centre</td>
<td>Take ADSB reports from the NUP network into the MEDUP network. Distribute ADSB report from the MEDUP network into the NUP network.</td>
</tr>
<tr>
<td>Padova</td>
<td>Italy</td>
<td>MGS and shadow mode ATC centre</td>
<td></td>
</tr>
<tr>
<td>Brindisi</td>
<td>Italy</td>
<td>MGS and shadow mode ATC centre</td>
<td></td>
</tr>
<tr>
<td>Cagliari</td>
<td>Italy</td>
<td>MGS</td>
<td></td>
</tr>
<tr>
<td>Madrid (AENA Experimental Centre and Paracuellos site)</td>
<td>Spain</td>
<td>MGS and shadow mode ATC centre</td>
<td></td>
</tr>
<tr>
<td>Baleares</td>
<td>Spain</td>
<td>MGS</td>
<td></td>
</tr>
<tr>
<td>Malta</td>
<td>Malta</td>
<td>MGS</td>
<td></td>
</tr>
<tr>
<td>Monastiri</td>
<td>Greece</td>
<td>MGS</td>
<td></td>
</tr>
<tr>
<td>EEC (Bretigny)</td>
<td>France</td>
<td>ISDN/IP router</td>
<td>Take ADSB reports from the MEDUP network through NUP server in Langen.</td>
</tr>
<tr>
<td>DFS (Langen)</td>
<td>Germany</td>
<td>ISDN/IP router NUP ADSB Server</td>
<td>Take ADSB reports from the MEDUP network. Distribute ADSB report from the NUP network.</td>
</tr>
</tbody>
</table>

Table 5 – Configuration of MEDUP sites

3.3.2-Italian MEDUP Infrastructure

3.3.2.1-MGS (Italian sites, Greece and Malta)

The CNS/ATM ground station (referred to as MGS – Medup Ground Station) represents the core components of the ground infrastructure. The MGS is composed by:

- **VDL Mode 4 base station transponder, which guarantees the necessary VHF coverage and the access to the channel according to the ICAO VDL Mode 4 datalink standard. The transponder is equipped with two VHF transceivers.**

- **GNSS receiver capable to compute differential corrections, which are exploited by the GRAS service.**

- **PXI board computer hosting the so-called “ADSB Router” software. That software manages all the MGS functions:**
i. Reception of ADSB messages from the transponder

ii. Transmission of TISB, FISB and GRAS message to the transponder

iii. Transmission/reception of CPDLC messages to/from the transponder

iv. Networking module to remotely exchange data with other MGS (this function easily permits building a network of ground stations)

v. Interface with the ground shadow system to pass and receive messages

vi. Monitoring and control functions (with local and remote – via SNMP – operator access

- CISCO IP router
- RF filters, GPS and VHF antennas

The networking modules of stations have been linked via IP routers and ISDN 64 kbps line.

Figure 9 - Italian MGS, manufactured by AMS for ENAV, deployed in Rome, Brindisi, Padova, Monastir (GR), Malta

3.3.2.2-ATM Ground Systems (Italy)

The MEDUP ground system (ATM shadow system) is a fully-featured ATM surveillance and flight data processing system (ATMS), enhanced with the datalink applications selected for demonstration at the beginning of the project. It is capable to receive live data from operational ATC systems and combine this data with the surveillance information provided through ADSB. The overall surveillance picture can then be passed to the MGS network for uplink via TISB. A purposely-developed HMI prototype has been developed to provide datalink service access within the environment of the standard Controller Working Position used by the Italian ATC controllers.

The ATM shadow system is the ground user of the MEDUP VDL4 network. It exchanges messages with other ground and airborne users exploiting the services offered by the network. The ATMS processes the information gathered from the network, in combination with live data coming from operational ATC systems to which the ATMS is connected. Live data should include radar data and flight plan data.

The ATMS includes different components:

- Surveillance Data Processor (SDP), including Shadow Mode Gateway, ADS Processor and Data Fusion Processor
- Flight Data Processor (FDP)
- TISB Server
- **FISB Server**
- **Data Link Server (DLS) also called ATM Communication Gateway (ACG)**
- **Controller Working Position (CWP)**

The following table shows the details of the available functions:

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Function Name</th>
<th>Function description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACG</td>
<td>ATM Communication Gateway</td>
<td>The ACG implements all the protocols necessary to exchange data with the MEDUP network of VDL4 Ground Stations and with the equipped aircraft (end-to-end protocols, like CPDLC ASE)</td>
</tr>
<tr>
<td>ADSP</td>
<td>ADS Processor</td>
<td>The ADSP is in charge to process ADSB reports (ADS tracking)</td>
</tr>
<tr>
<td>SMG</td>
<td>Shadow Mode Gateway</td>
<td>The SMG is capable to safely receive radar and flight plan data from the operational ACC centre, without interfering with the operational data processing.</td>
</tr>
<tr>
<td>DFP</td>
<td>Data Fusion Processor</td>
<td>The DFP is the main surveillance data processor of the MEDUP system, capable to combine surveillance information from radar and ADSB data sources. For ADSB equipped aircraft, the DFP produces a unique system track applying an algorithm that takes into account the relative accuracy of each source.</td>
</tr>
<tr>
<td>FDP</td>
<td>Flight Data Processor</td>
<td>The FDP is in charge to manage the flight. While progressing each flight from pending to active, live and termination state, the FDP continuously estimates and updates the projected aircraft trajectory, and use this information to activate automatic and manual coordination process with adjacent MEDUP systems through AIDC application. The FDP is also in charge to perform the FLIPCY service (request of the FMS-stred flight plan and comparison with the ground-stored flight plan).</td>
</tr>
<tr>
<td>TIS</td>
<td>TISB Server</td>
<td>The TISB Server periodically gathers data from the Data Fusion Processor related to the whole surveillance picture and passes (via the ACG) single TISB messages to one or more MGS for broadcasting. The whole surveillance picture is split in multiple TISB messages that are transmitted by the best-positioned MGS(s). The TISB Server can work in both gap-filler mode and in full-picture mode.</td>
</tr>
<tr>
<td>FIS</td>
<td>FISB Server</td>
<td>The FISB Server gathers ATIS data related to one selected airport and and passes (via the ACG) FISB messages to one or more MGS for broadcasting.</td>
</tr>
<tr>
<td>CWP</td>
<td>Controller Working Position</td>
<td>The CWP is the human-machine interface for the controller. It combines radar and ADSB traffic visualization (including CAP data), flight plan management, DLL/ACL/ACL message exchange.</td>
</tr>
</tbody>
</table>

*Table 6 – Main MEDUP ATM shadow system functions (Italy)*
3.3.2.2.1-Rome ATM Shadow Systems

The MGS ground station is installed on top of the Rome ACC centre building, next to the Ciampino airport. The ground station exchanged ADSB and other datalink related information with the shadow system located at the ENAV Experimental Centre in Rome via ISDN connection. The shadow system also receives live radar data from the Rome ACC surveillance data processing system.

The following picture shows the architecture of the MEDUP site in Rome.

**Block Diagram of the MEDUP ATM Experimental System - Rome Site**

![Block Diagram of the MEDUP ATM Experimental System - Rome Site](image)

**Figure10 – Architecture of the MEDUP Rome system**

**Figure11 - Picture of the CWP in Roma Shadow system**
3.3.2.2.2 - Padova and Brindisi ATM Shadow Systems

The MGS ground station is installed on top of the ACC centre building. The ground station exchanged ADSB and other datalink related information with the co-located shadow system. The shadow system receives live radar data from the operational room, in the same building.

The following picture shows the architecture of the MEDUP site in Padova and Brindisi.

**Block Diagram of a MEDUP ATM Experimental System - Padova site**

**Figure 12 - Architecture of the MEDUP shadow systems for Padova and Brindisi sites**

**Figure 13 – Typical VHF and GPS antenna installation (Padova site)**
Figure 14 - Picture of the CWP in PadovaShadow system (A) - Brindisi shadow system (B)
3.3.2.3-Airborne System: Italian aircraft

A turboprop Beech Aircraft 200 (registration number I-PIAH), managed by Interfly airliner, has been equipped by ENAV/AMS for the flight trial. The airplane was fitted with the MEDUP airborne system composed by:

- a VDL Mode 4 transponder
- a CDTI with HMI for ADSB/TISB data and for CPDLC

Moreover the aircraft was purposely equipped with an air data computer that gathered the following information from the avionic sensors:

- barometric pressure altitude
- airspeed
- magnetic heading
- vertical speed

The airdata computer passes these information items to the CDTI and then to the VDL Mode 4 transponder for broadcast via ADSB reports.

The following pictures show the solutions adopted to install MEDUP equipment on board.

Figure 15 – VDL Mode 4 transponder (a) and CDTI (b, c) installed for the MEDUP flight tests
3.3.3-Spanish MEDUP Infrastructure

The Spanish MEDUP infrastructure is made up of the Ground and Airborne systems, as shown in Figure 16 – Spanish MEDUP infrastructure elements.

3.3.3.1-Ground System

The Ground Spanish MEDUP system is composed by two ground stations, located at Madrid and Palma de Mallorca and a Shadow Mode ATC System, called ECA-UP, located at the Aena Experimental Centre in Madrid. The two ground stations are interconnected with the ECA-UP system using the Spanish ATC Wide Area Network REDAN. Furthermore, the Spanish MEDUP ground infrastructure is connected with the rest of the MEDUP network through a connection with Rome. These interconnections are depicted in Figure 17 – Spanish MEDUP Ground System interconnections below.
The two Spanish VDL Mode 4 ground stations, manufactured by CNS Systems, are located respectively in Paracuellos (Madrid) and Randa (Mallorca). Both ground stations exchange ADS-B and other services information with the shadow system ECA-UP, located in Madrid, through the wide area network REDAN.

Figure 18 – Antennas (a) and GS (b) installed in Paracuellos (Madrid)
The ground stations are composed by the following subsystems:

- **VDL Mode 4 Transponder**, which performs communications over the digital radio link, i.e. receives downlink messages and transmits uplink messages, in accordance with the ICAO VDL Mode 4 standard. The VDL Mode 4 transponder is connected to one VHF transmitter and one VHF receiver antenna.

- **GNSS Reference Receiver**, which receives information from the GPS satellite system and utilizes this information in the Ground Station to provide accurate timing and position. The timing information is provided to the VDL Mode 4 subsystem, which utilizes it for slot synchronization of the digital radio link. The timing information includes UTC time and a pulse per second signal (1 PPS).
  
  The GNSS reference receiver is configured with data of the exact position of the GPS antenna. Given this information, the GNSS reference receiver calculates the error of the position received from the GPS satellites and provides position correction information.

- **Data Management Subsystem (DMS)**, which constitutes a CPU card included in the Compact PCI (Peripheral Component Interconnect) computer unit, performs the routing of data between the VDL Mode 4 subsystem and the ground network (the Service Interface) as well as between ground station subsystems. The DMS performs the necessary data conversion, generation of messages and routing of data that is required for each service application.

- **Monitoring and Control Subsystem (MCS)**, which constitutes a CPU card included in the Compact PCI (Peripheral Component Interconnect) computer unit, performs monitoring of status and function of all subsystems, control functions as well as logging. The MCS provides Simple Network Management Protocol (SNMP) support over the remote access interface for monitoring and alarm functions.

- **Power Supply Subsystem**, which distributes power to the internal units that require AC power.

- **Sensor Subsystem**, which monitors the climatic conditions inside the cabinet/rack as well as intrusion into the rack.

The services that the two Spanish Ground Stations support, include:

- **ADS-B Service**: The Ground Station receives ADS-B messages on the configured radio channel(s). These messages are decoded and translated by the DMS into Asterix 21 and output on the service interface to
supply the ground recipient with ADS-B information from the mobiles. The Ground Station, thanks to this service, also periodically sends a specific Ground Station ADS-B message.

- **TIS-B Service**: The Ground Station receives TIS-B messages from an external TIS-B server on the Asterix data format via the service interface to the DMS. The DMS converts these data to the format required for transmission over the VDL Mode 4 radio link and transfers the messages to the VDL Mode 4 subsystem for tunnelling over the VDL Mode 4 radio link.

- **FIS-B Service**: The Ground Station receives FIS-B data from an external FIS-B server via the service interface to the DMS. The DMS transfers the messages to the VDL Mode 4 subsystems for tunnelling over the VDL Mode 4 radio link.

- **DGNSS (GRAS 1) Service**: Satellite data is received by the GNSS reference receiver and transferred to the DMS. The DMS generates the GRAS type 1 message (which includes, among other data, pseudorange corrections and range rate corrections) and sends it to the VDL Mode 4 subsystem for tunnelling over the VDL Mode 4 radio link.

- **Point-to-point Service**: This service provides the capability to exchange point-to-point messages (e.g. CPDLC messages) over the radio link and over the ground network.

### 3.3.3.1.2-Madrid ATM Shadow System – ECA-UP

ECA-UP is an ATC system that incorporates ADS, ADS-SSR integration, CPDLC, and some other advanced capabilities. The system, located at the Aena Experimental Centre in Madrid, has two controller working positions and is connected to the Spanish MEDUP infrastructure through the wide area network REDAN, and to the rest of the MEDUP network through a connection with Rome.

ECA-UP has been developed as evolution of the ECA system. ECA is an ATC system that includes ADS-C and CPDLC functionalities through FANS-1/A.

![ECA Controller Working Position (a) and MEDUP Network Monitoring (b)](image)

*Figure 20 – ECA Controller Working Position (a) and MEDUP Network Monitoring (b)*

ECA-UP main functions are briefly described below:

- **Surveillance data processing:**
  - SSR, ADS-B (through VDL Mode 4 technology) and ADS-SSR tracking: The main purpose of the tracking function is to improve accuracy and availability of the positional data (ADS and/or SSR data) being received from aircraft.
  - CAP (Controller Access Parameter) service, which, through the ADS-B tracking, provides the controller with relevant data sent by the aircraft navigation equipments
  - Short-term conflict alert (STCA).
• Conformance monitoring: out-of-conformance indication when differences (deviations) between ADS-B reported position and multi-radar position or between tracking data and flight plan data stored, exceed a pre-defined tolerance limit.
• Management and display of ADS-B planned routes.
• Flight plan data processing
• Supervision and monitoring of the different subsystems
• Data link services:
  • ADS-B MEDUP messages processing
  • Controller-Pilot Data Link Communications (CPDLC) service
  • Communications management (CM) service
  • TIS-B service
  • FIS-B service
  • ATS Interfacility Data Communications (AIDC) service
• Communications management (ADS-B router):
  • Connection management
  • Ground-Air broadcast communications management (TIS-B and FIS-B)
  • Communications management (ADS-B)
  • Mobility management: Mobility Binding Table (MBT) maintenance
  • Domain Name System (DNS) management
  • Ground stations configuration
  • ADS-B router configuration
Additionally, from the ECA system previous capabilities:
• Aircraft data management
  • Automatic management of ADS-C contracts.
  • Automatic management of Controller-Pilot Data Link Communications (CPDLC)

The following table summarizes the main components of the ECA-UP architecture, also shown in Figure21 - Hardware block diagram of the ECA-UP:

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>COM</td>
<td>Communications and Aircraft Data Processor</td>
</tr>
<tr>
<td>TDV</td>
<td>Surveillance Data Processor</td>
</tr>
<tr>
<td>TPV</td>
<td>Flight Plan Data Processor</td>
</tr>
<tr>
<td>TSV</td>
<td>Supervision Terminal</td>
</tr>
<tr>
<td>CWP</td>
<td>ECA-UP has two Air Traffic Control Working Positions, each made of:</td>
</tr>
<tr>
<td></td>
<td>o 1 Traffic Display Terminal (TPT)</td>
</tr>
<tr>
<td></td>
<td>o 1 Messages (ADS and Flight Plan messages) Display Terminal (TPM)</td>
</tr>
<tr>
<td></td>
<td>o 1 Data Link Terminal (TED)</td>
</tr>
</tbody>
</table>
Sed Datalink Server
UAST Asterix Data Acquisition Unit
SIMAC ADS-SSR and CPDLC Simulator
- ATN Router
- RDSI Router
- Internal and External LAN
- Printers

Table 7 - Main components of the ECA-UP architecture

Figure 21 - Hardware block diagram of the ECA-UP

3.3.3.2-Airborne System - Spanish Aircraft

Aena has been furnished by SENASA with a Beechcraft King Air A-100 (see Figure 22 – Spanish Aircraft) with the licence number EC-CHE. The aircraft is devoted to Aena experimentation in several fields.
The ADS equipment installed onboard is composed by:

- An ADS-B transponder, manufactured by CNS Systems and with VDL Mode 4 technology (see Figure 23 (a)), which receives position and time information from the GPS receiver and manages the data link transmissions
- A CDTI (see Figure 23 – VDL mode 4 transponder (a) and CDTI (b) in rack-(b)), manufactured by Eurotelematiks, which presents surveillance information about the surrounding traffic to the flight crew. The CDTI in the Spanish aircraft is located in central position of the front panel (best possible position). With this configuration both pilots will have access to the CDTI.

The system installed onboard is shown in Figure 24.
3.3.4-Infrastructure deployed in Greece and Malta

The MEDUP infrastructures deployed in Greece (Monastiri site in eastern Peloponnese at about 1000 m elevation) and in Malta (Luqa airport) are quite similar to the Cagliari one in terms of equipment, connections and functions.

The MGS deployed in Greece is installed at Monastery (SW Peloponnese); technically, it is identical to the MGS’s of Italy (from where it has been taken/provided courtesy of ENAV) as seen from its description in Para.3.3.2-Italian MEDUP Infrastructure (pg.30/85).

The site (Monastery) was so chosen that it be distant from any Navaids installations for the fear of interference; it is a mountain top, 1067 meters elevation (the highest in its vicinity), located at: 37 deg 12’ 55” N - 21 deg. 49’ 06” E.

The host building is used for telephonic services (wire/wireless/mobile) and air-navigation telecommunications (frequencies servicing both Greece and Malta) – and, of course, as of early 2004, for the MGS.
Figure 25 - Host building and antennae at Monastery

Figure 26 - Equipment room at Monastery.

The theoretically predicted coverage from Monastery fulfilled (actually surpassed) the operational
requirements; and, especially, those concerning the lack of any discontinuity (or void) in the coverage between the Malta & Monastery MGS’s or between the Brindisi & Monastery MGS’s.

The excellent qualifications of the Monastery site were demonstrated during the flight trials (see flight ENAV 17-11-04 in para 4.1.1 below)

3.3.5-Results of Technical Tests

This Paragraph reports the Ground System technical tests (both local and integrated ones) and any technical tests with a/c equipment on ground. It summarizes all tests of these types performed both in Sub-Phase A2 and in Phase B.

Results and comments are given with such details as appropriate for the scope of the Final Report.

The Section is subdivided into three parts regarding respectively:

- Tests performed by ENAV with the Italian system and the Greek and Maltese infrastructures
- Tests performed by AENA with the Spanish system
- Interoperability tests performed with different equipment and infrastructure, both by ENAV and AENA.

It should be further noted that the Verification flights (also the limited area or limited scope ones) are described in Chapter 4.1 because of their close inter-relationship with large-scale flights.

3.3.5.1-Tests of Italian system and of Greek and Maltese infrastructures

Integration tests concerning the Italian system were performed according to an incremental approach due the phased deployment of all its components, which occurred in both phase A2 (Roma and Padova sites) and Phase B (Brindisi, Cagliari, Greece and Malta sites). From a technical point of view, systems deployed in Greece (Monastiri) and Malta (Luqa Airport) can be considered an extension of the Italian part.

Integration test were planned in the document “MEDUP Integrated Test Plan (ITP)” [22]. That document provided the framework for all MEDUP testing activities to be performed before starting the flight trials phase. The ITP included all necessary test procedures for the verification of correct implementation and interoperability among systems (ground and airborne) and applications developed within the WP3.

During integration tests, the real MEDUP airborne systems, actually grounded, were used to stimulate the ground systems, in order to reproduce as much as possible the actual environment of a real flight. The following set-up was prepared:

- Airborne transponder and CDTI were properly linked
- Airborne transponder was connected to a portable GPS antenna to get time synchronization for the VDL 4 link
- Airborne transponder was connected to a portable VHF antenna to establish radio link with the MGS

The completion of integration tests was a precondition to perform the interoperability tests.

Hereafter, the categories of tests performed are summarized.

Test ground network, TCP/IP connections between MGSs

This test verified that that all ISDN/IP connections between MGS pairs were correctly established, so that one MGS could be able to communicate with each other (with unicast and multicast protocols). The test also covered the verification of the DNS (Domain Name System) service for translation between hostnames and IP addresses.
Test ADSB air-to-ground, link between airborne transponder and MGS
This test verified that ADSB messages generated and transmitted by the airborne system were received by the MGS, passed to the ATMS, processed and visualised on airspace graphical maps.

Test ADSB air-to-air, link between airborne transponders
This test verified that ADSB messages generated and transmitted by one airborne system were received by another, passed to the CDTIs and visualised on the CDTI maps.

Test TISB ground-to-air
This test verified that the surveillance traffic picture generated by the SDP was transformed into the proper set of TISB management and target messages, which are then broadcast by one suitable MGS, received by the airborne transponder and visualised on the CDTI maps.

Test FISB ground-to-air
This test verified that ATIS messages were formatted as FISB messages and broadcast by one suitable MGS, received by the airborne transponder and visualised on the CDTI.

Test GRAS ground-to-air
This test verified that the MGS broadcast the differential correction messages with the information gathered by its internal differential GPS receiver.

Test CPDLC (including DLL, ACL, ACM)
These tests verified that all implemented CPDLC messages (covering DLL, ACL, ACM services) were correctly exchanged between the ground and the airborne systems. The capability to exchange CPDLC data with different a/c covered by different MGS is confirmed. The shadow system can exchange CPDLC message with any number of aircraft with no limitations concerning the MGS to be used. The AR software is capable to handle transparently which ground station is to be used to communicate with an a/c.

Figure 27 - CDTI during laboratory test (details: flight plan, TISB data)
Test AIDC and ACM transfer
Coordination and transfer of control supported by AIDC.

Test FLIPCY
The test verified that the flight plan stored on board the CDTI can be downlinked on ATMS request and exploited by the ATMS to perform a check with the flight plan stored in the FDP

3.3.5.2-Tests of Spanish System
AENA has been performing tests in the equipment of the Spanish MEDUP system from an early stage of the development phase.
For each MEDUP service implemented in the system and for each element of the system, the following tests have been performed:
- Factory Acceptance tests: to detect potential bugs as early as possible
- Site acceptance tests: with equipment affected by conditions of final location.

Site acceptance tests were performed following an incremental approach:
- Tests of broadcast applications at the ATM platform (ECA-UP) with simulated traffic
- Tests of broadcast applications at the ECA-UP platform plus the ground stations (fed with simulated traffic)
- Tests of broadcast applications with the end-to-end system: CDTI connected to VDL mode 4 transponder exchanging (transmitting and receiving) by radiofrequency messages with a VDL mode 4 Ground Station, which through the REDAN network is connected to the ECA-UP ATM platform.
- Tests of point-to-point applications at the ATM platform (ECA-UP) with simulated traffic
- Tests of point-to-point applications at the ECA-UP platform plus the ground stations (fed with simulated traffic)
- Tests of point-to-point applications with the end-to-end system: CDTI connected to VDL mode 4 transponder exchanging (transmitting and receiving) by radiofrequency messages with a VDL mode 4 Ground Station, which through the REDAN network is connected to the ECA-UP ATM platform.

Once each element of the system had been tested individually for each specific service, the end-to-end system was tested with all elements on ground (i.e. the onboard transponder and the CDTI connected to an
external power unit and located on ground).
That was the nearest one can get during testing of equipment to the conditions encountered during a real flight trial, but without actually flying. Those end-to-end tests proved really useful to detect problems or even bugs before a flight, and therefore, to concentrate during the flight in collecting useful data by avoiding as much as possible unexpected problems once the aircraft was on air.
Whenever a flight was scheduled in Spain, a set of end-to-end tests were always performed before the flight. The system configuration used in the end-to-end tests is shown in the next picture:

![Figure 29 - Spanish System configuration for ground end-to-end tests](image)

According to the “MEDUP Integrated Test Plan (ITP)” [22] document, the tests were categorised in:
- test ground network, TCP/IP connections between MGSs
- test ADSB air-to-ground, link between airborne transponder and MGS
- test ADSB air-to-air, link between airborne transponders
- test ADSB message reception from the NUP ADSB Server
- test TISB ground-to-air,
- test FIS-B ground-to-air,
- test GRAS ground-to-air,
- test CPDLC (including DLL, ACL)
- test AIDC and ACM transfer

### 3.3.5.3-Interoperability Tests

Interoperability tests were particularly relevant in the MEDUP project for two main reasons:
- Different equipment manufacturer used by the partners to implement the same MEDUP subsystem (e.g. airborne transponder manufacture by SAAB for the Italian aircraft and by CNS Systems for the Spanish aircraft)
- Interoperability requirements with the NUP project, between the networks and between VDL4 equipment

Therefore, interoperability tests always involved at least two partners and were usually more complex that integration tests performed by each single partner.
The following interoperability tests were performed.
Interoperability between Italian and Spanish part of the MEDUP network and shadow ATM systems

This ground test verified that:

- The TCP/IP connection over ISDN line between the Italian and the Spanish part of the MEDUP network worked properly
- ADS-B reports collected by one of the Spanish (Italian) MGS were also available at one of the Italian (Spanish) ATM shadow systems
- AIDC application protocols implemented at the Italian and Spanish sides were interoperable

Interoperability between SAAB and CNS System VDL 4 equipment within MEDUP

The interoperability between VDL 4 equipment coming from different manufacturers (SAAB Transpondertech and CNS Systems) was one of the main issues faced during the project, particularly for applications not yet stated within the VDL Mode 4 Technical Manual of ICAO (TISB, FISB, GRAS, POINT-TO-POINT).

The tests verified that:

- ADS-B reports transmitted by a transponder were correctly received by transponders of a different vendor. The successful results of this test permitted to arrange in Italy on 6-10-2004 a demonstration flight that involved one MEDUP aircraft and one NUP aircraft (see Chapter 4.1.5 below).
- TIS-B and FIS-B messages transmitted by one ground station transponder were correctly received and processed by an airborne transponder of another vendor
- GRAS messages transmitted by the Italian MGS were correctly received by an airborne transponder from CNS Systems. Received GRAS messages (differential corrections) were not processed by the CNS Systems transponder for reasons not fully clarified.

Interoperability tests within CAP application were not feasible due to different solutions adopted by MGS providers during the project.

In order to minimize the risks of encountering interoperability problems during the flights with the Spanish aircraft, AENA personnel traveled twice to Italy with the airborne equipment, in order to ensure with ground tests that interoperability existed between systems in all services.

Interoperability was successfully checked in the following services:

- ADS-B
- TIS-B
- FIS-B

As regard the CPDLC application, the interoperability was only demonstrated on the ground when the Spanish aircraft flew to Italy (December 2004). During that tests, CPDLC messages were correctly exchanged between the Italian ground system and the Spanish transponder+CDTI.

Lack of interoperability existed in the CAP service as different implementations were selected by ENAV and AENA (see above).

Regarding GRAS service, messages sent by Italian ground stations were accepted by the CNS transponders although information contained in the messages did not follow the required format so that they could not be directly used.

Regarding the AIDC service, several tests were performed before the real flights occurred, verifying successful interoperability at protocol level. All the coordination phases (Notification, Coordination,
Transfer) from Rome to Madrid were successful. The coordination from Madrid to Rome was only verified for the Notification; lack of time didn't allow to have Coordination and Transfer working in the Italian system.

**Interoperability between MEDUP and NUP ground networks**

One of the objectives agreed between MEDUP and NUP projects was to demonstrate the feasibility of a seamless European ADS-B network, capable to provide ADS-B information to users irrespective of their location. Therefore a connection was set-up between the Rome MGS and the NUP ADS-B server located in Langen. This test verified that:

- ADS-B reports received by one MGS could be received and processed by a server of the NUP ADS-B network
- ADS-B reports available at one server of the NUP network could be received and processed by a MGS

![Figure 30 – MEDUP -NUP Physical Network Connection](image)

![Figure 31 – MEDUP -NUP Logical Data Flow](image)
4. Flight Trials

4.1 Flight Trials for Verification and Demonstration

This Chapter is devoted to a summary, appropriate for the scope of the Final Report, of the flight trials performed, starting in December 2003 and completed in December 2004 for a total of about 85 flight hours. The objective of the present Chapter is to give an overview of results obtained both in terms of what has been assessed and in terms of some open issues.

The flight tests performed were of different types, performed in a mixed sequence:

- Limited area, limited scope tests in flight, mainly for technical verification
- Large area tests in flight both for technical verification and for operational demonstration
- Interoperability tests in flight, of paramount importance

It should also be considered that the needs of MFF in terms of MEDUP infrastructures were well present especially in terms of coverage verification in the MFF testing area in the Tyrrhenian Sea, at relatively low FLs.

It is noted that the detailed Flight test results are reported in the individual Flight Reports, available from WP 4 deliverables and also provided in the MEDUP Web Site.

As above mentioned, the different type of tests were actually performed not always in proper sequence and in some cases it has been necessary to come back to limited scope tests even during large area tests to verify issues arisen at a later stage.

However, in the present Final Report the results are appropriately synthesized along the logical path and not according the historical flow.

Most flights have been performed using shadow mode ATC Centres, manned with Controllers that monitored the experimentation in parallel with those on duty in the operational ACC. At the same time, on board of the equipped a/c during demonstration flights, information broadcast from ground or transmitted point-to-point has been visualized on the CDTI.

Operators on ground and on board have expressed significant interest in the possible use of the MEDUP services. However, due to the limited time actually available after all the necessary technical tuning, no intensive and focused Operator involvement has been possible and thus deep pre-operational evaluation has not been feasible.

The following paragraphs will cover in adequate details the technical points assessed, especially regarding coverage (including the environment effects) and continuity for the different applications, grouped for broadcast air to ground, broadcast ground to air, point to point.

4.1.1 Coverage performance (air to ground for to ADS-B application)

The coverage issue has been investigated in several steps but their results are here summarized as conclusions, although still not definitive.

Two different criteria have been used to assess coverage by each of the installed MGS. The first one uses the following parameters:

- percentage of received versus transmitted messages higher than 95 %
- ADS-B message repetition rate 2 sec
- averaging period: 1 minute (60 sec) sliding window
This criteria is in the following called conventionally 95%/60 sec

The second one, worked out after a suggestion by HCAA, is aimed to the use of ADS-B as surveillance means, alternative to radar or complementary to it.

In this connection the coverage performance definition should be as close as possible to the one customarily used for radar, which generally refers to a blip-to-scan probability of 50 % or higher within the coverage area.

Before defining in detail this second criteria, it is useful to consider the different operation of Radar and ADS-B.

Both ADS-B and Primary/Secondary Radar have the same operational objective but they perform their role in different technical way.

Radar scans the airspace, detects echoes (primary), or answers to own interrogation (secondary) and measures range and direction of the detected object. The characteristics relevant to our comparison with ADS-B are the antenna scanning rate and transmitter power/receiver sensitivity which influence the detection range.

Typically, for a long range secondary radar devoted to en route surveillance, the scanning rate is 5 or 6 rpm (12 or 10 sec between successive scans) and range is of the order of 200 NM with a single scan probability (blip to scan) better than 50 %.

ADS-B Ground Station receives messages broadcast from a/c ADS-B transponder: the messages from a specific a/c contain identification and position as determined by the on board navigation system, and other additional information such as intent, etc.

The message repetition rate (typically one every two to five sec for en route applications) is somewhat comparable to radar scan rate. The percentage of correctly received messages is somewhat comparable to the radar probability of detection.

Both surveillance means have their raw data processed in a tracking system which provides “continuous” and extrapolated positions of a/c to displays/computers for operators (controllers). Where both surveillance means are available the tracking system may provide an appropriate “fusion” of data.

When considering ADS-B, one might use the higher rate of message repetition (typically several times that of radar scanning rate) to accept a lower probability of correct reception of a single message and thus reach a longer range and a larger coverage.

It can be considered acceptable from the point of view of the ADS-B message processing/tracking that in each sliding string of six transmitted messages (from each a/c) at least three will be correctly received. With a message repetition rate of 2 sec, every 12 sec there will be one processed position information.

It is here recalled that, for the purpose of en route surveillance, 12 sec of information update is considered operationally adequate.

Although not rigorously correct, this may amount to define the ADS-B coverage in a way similar to radar (50 % blip to scan with 12 sec of scanning rate). The parameters are:

- percentage of received versus transmitted messages higher than 50 %
- ADS-B message repetition rate 2 sec
- averaging period: 12 seconds sliding window

This second criteria is in the following called conventionally 50%/12 sec

4.1.1.1. ADS-B coverage measured in ENAV flights (air to ground)
Using the information stored during a sample of the ENAV technical verification flights, an overview of coverage performance has been made using both definitions. The relevant charts are included for information.

*Flight ENAV 27-5-04*

Flight leg Brescia to Brindisi (FL 230, 230 knots, coverage from Brindisi MGS):

95%/60 sec range (see below)  
50%/12 sec range about 150 NM

Using one minute sliding window, the acquisition range with 95 % percentage of correctly received messages can be estimated at about 105 NM, because of a small number of holes. However the percentage is consistently over 90 % starting from 136 NM.
Flight ENAV 27-7-04

Figure 33 – Flight of 27-07-2004

Flight leg Rome to Cagliari (FL 230, 240 knots, coverage from Ciampino MGS):
95%/60 sec range about 142 NM.
50%/12 sec range about 167 NM

Flight leg Cagliari to Rome (FL 230, 230 knots, coverage from Ciampino MGS):
95%/60 sec range about 127 NM.
50%/12 sec range about 133 NM

Flight leg Rome to Parma (FL 200, 220 knots, coverage from Ciampino MGS):
95%/60 sec range about 130 NM.
50%/12 sec range about 143 NM

Flight ENAV 17-11-04
Figure 34 – Flight of 17-11-2004

Flight leg Brindisi to Greece and Crete (FL 270, 235 knots, coverage from Monastiri MGS):
This flight leg has been analyzed with more detail and its experimental coverage performance has been compared with coverage calculated taking into account terrain and obstacle masking
95%/60 sec range: see below 50%/12 sec range about 152 NM
The performance is somewhat erratic, partially explained by calculated small holes, and while long periods of >95% are present from about 142 NM, stable coverage at >95% is reached only at about 102 NM. Investigation to be completed and to be included is an examination of lobing over see and/or diffraction over obstacles.

Flight leg Crete to Malta (FL 270 then FL245, 235 knots, coverage from Monastiri MGS):
95%/60 sec range about 130 NM. 50%/12 sec range about 154 NM
It should be noted that the part of the flight near Crete, about 100-120 NM from Monastiri, does not show solid coverage. Some explanation may be found in several calculated holes, but further investigation is needed as noted above for Brindisi Crete leg.
The range of 154 NM (where the coverage is lost towards Malta) corresponds pretty well to the calculated range, as limited by terrain masking.
4.1.1.2. Coverage measured in AENA flights

**Air to ground coverage**

The results presented below summarize the conclusions obtained from the “air to ground” coverage evaluation of the seven flights that have been carried out by AENA within the MEDUP context. Detailed results for each flight and each MEDUP Ground station are available in the individual Flight Reports. Some remarks have to be considered:

- Throughout the seven flights, the ADS-B service performance has been improved. The coverage evaluation results referred in this report belong to AENA’s latest flights. These results give better information about the real performance of the application.
- Antenna site within a high interference environment in the VHF band (due to limitations in available locations for experimental installations) limits the performance of the ADS-B service. Although these interferences have been reduced in the case of Paracuellos MGS (by using an additional filter just after the receiving antenna), results obtained from the evaluation of coverage “ground to air” indicate that performance of ADS-B service can be improved if the site of MGS antenna is carefully optimised.
- Coverage evaluation has been performed in directions, ranges, and flight levels that were imposed by operational needs.

An overview of “air to ground” coverage performance has been made up using the following parameters:

- ADS-B transmission rate: 1 message per 2 seconds
- Averaging period: 1 minute (60 sec) sliding window
- Percentage of received vs transmitted messages: higher than 95%


The following picture shows the trajectory flown by the aircraft (during two different flights) and the percentage of messages received for each position at Paracuellos MGS. The reception percentage is indicated according to the colour scale on the right side. The averaging period is 60 seconds.

ADS-B reports have been gathered just before reaching the ADS-B router. Because of this, reports with position information outside the service volume have also been considered in the coverage evaluation. ADS-B reports with a position outside the service volume are discarded by the ADS-B router, and do not reach the ATM system. Nevertheless, they have been included in the analysis in order to evaluate the real coverage of the MGS.
Figure 35 - Percentage of received messages at Paracuellos MGS. Averaging period 60 sec.

As it can be observed from the figure above, the percentage of reception is high in proximity to the MGS location (over 80% in a radius of 80-100NM from the MGS). 

*Flight AENA 15-12-04*

Flight leg Madrid to Reus (FL 180, coverage from Paracuellos MGS):

- 95%/60 sec range: see below
- 50%/12 sec range about 84 NM

Sporadic periods with more than 95% of correctly received messages are achieved up to 115 nautical miles from the MGS. This percentage is consistently over 80% up to 110 nautical miles far from the MGS.

*Flight AENA 21-12-04*

Flight leg Reus to Madrid (FL 170-210, coverage from Paracuellos MGS):

- 95%/60 sec range about 110 NM
- 50%/12 sec range about 115 NM

Using a one minute sliding window, the acquisition range with >95% percentage of correctly received messages can be estimated at about 110 NM. Nevertheless, this percentage actually oscillates between 93% and 97% starting from that range.

Reception of ADS-B messages extends beyond the service volume border. Nevertheless, the percentage of received messages turns to be irregular when approaching the service volume border (*this is not actually a technical performance border but only an operational one*), as it oscillates between 50% and 97%.

The area around Matacan is rather lacking in reception because the aircraft is too low. The aircraft is based at Matacan airport.
The following table gives an overall figure of expected ADSB messages against the ones actually received at Paracuellos MGS. Expected message numbers are estimated taking into account the period of time from the first received message to the last received message as well as the transmission rate onboard.

<table>
<thead>
<tr>
<th>Date</th>
<th>15/12/2004</th>
<th>21/12/2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Range(^2)</td>
<td>138 NM</td>
<td>143 NM</td>
</tr>
<tr>
<td>Expected ADSB messages (A)</td>
<td>1959</td>
<td>1727</td>
</tr>
<tr>
<td>Received ADSB messages (B)</td>
<td>1612</td>
<td>1535</td>
</tr>
<tr>
<td>Ratio (B/A)</td>
<td>0.82</td>
<td>0.88</td>
</tr>
</tbody>
</table>

Table 8 - OverallRatio of received messages to expected messages at Paracuellos MGS.

Ground to air coverage

An additional information is of relevance and regards the performance of ADS-B messages in ground to air link. The “ground to air” coverage shows in fact better performance than “air to ground”. As the link budget is the same in both uplink and downlink, we conclude that the poorer results in the downlink must be the result of the VHF interferences on the MGS receptions. These interferences are reduced by using an additional filter just after the receiving antenna of the MGS, but may still affect to its performance. In any case, the results obtained by AENA in the “ground to air” coverage should be considered as a reference of the performance of the link.

The results presented below summarize the conclusions obtained from the “ground to air” coverage evaluation of the seven flights that have been carried out up to December 2004. Detailed results for each flight and location with a MEDUP Ground station are available in the individual Flight Reports, as mentioned above.

The following pictures show the trajectory flown by the aircraft during two different flights and the percentage of ADS-B “Basic Ground” messages received on board at each position from Paracuellos MGS. The percentage of received messages is indicated according to the colour scale on the right side. The coverage performance has been evaluated using two different groups of parameters, depending on the flight. The parameters value is specified for each picture.

Flight 22-07-04:
- ADS-B transmission rate: 1 message per second
- Averaging period: 50 sec sliding window
- Percentage of received vs transmitted messages: higher than 95%

Flight 15-12-04 and 21-12-04:
- ADS-B transmission rate: 1 message each two seconds
- Averaging period: 60 sec sliding window
- Percentage of received vs transmitted messages: higher than 95%

(for details on computation algorithm, please refer to document MEDUP – Data analysis specifications, MEDUP-TEC-WP4.3-ENAV-060-R1, 5/4/2004[26]).

\(^2\) Maximum distance between the MGS and the position of the a/c, in which the MGS is still receiving from the aircraft.

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Figure 36- Percentage of received messages from Paracuellos MGS. Date: 22-07-2004

Figure 37- Percentage of received messages from Paracuellos MGS. Date: 15-12-2004
As it can be observed from the figures above, the percentage of received messages is higher than the one observed in the “air to ground” coverage evaluation. Reception of ADS-B messages onboard extends beyond the service volume border (up to 147 NM approx.), and the percentage of received remains over 95% up to 130 NM from the MGS (over 90% up to 142 NM).

As it was shown in the “air to ground” coverage evaluation, the percentage of received messages decrease sharply around Matacán because the aircraft is too low. The aircraft usually takes off and lands at Matacán airport.

The “ground to air” coverage evaluated from the ADS-B messages received on board is also considered as a reference for the other “ground to air” broadcast services.

4.1.1.3. General considerations on ADS-B coverage

**Free Space performance** is related to the theoretical limitation due to inherent characteristics of the Data Link (tx power, rx sensitivity, antenna pattern and gain, modulation/demodulation performance, etc).

The latter characteristics and specifically the receiver/demodulator sensitivity should adhere to the ICAO SARPS (Annex 10, Volume III, Part I, Chapter 6.9) i.e. receiver should operate correctly with –114.5 dBW/m² power density.

With transmitter power of 10 W, antenna gains of 0 db and a margin of 1 db, this amounts to about 216 NM in free space, when neither earth curvature nor obstacles hinder the connection. The VDL Mode 4 system is designed for a range of 205 nm.

Actually the Transponders used in MEDUP may not be completely compliant, especially for the receiver/demodulator sensitivity. In fact at the beginning of MEDUP Programme both manufacturers (CNS
Systems and SAAB) had available Transceivers models of analog design and structure not providing the performance required by ICAO SARPS and ETSI EN’s.

Another important factor is the siting of antennas in the proximity to other VHF transmitters. Especially VHF AM voice transmissions with radio equipment developed according to old standards will cause interference and blocking of ADS-B message reception. Site survey and/or alternatively the use of filters has to be considered to protect ADS-B reception and range performance.

**Earth Curvature effects**

There are considerations on coverage constraints due to the effect of the earth curvature, which reduces the range in relationship to the FL of the a/c (see table below, computed for Ground Station at sea level and with standard atmosphere).

<table>
<thead>
<tr>
<th>Flight Level (Ground Station at sea level)</th>
<th>Horizon limitation in NM</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>250</td>
<td>Actual range is limited by free space range (216 NM)</td>
</tr>
<tr>
<td>400</td>
<td>224</td>
<td>Actual range is limited by free space range (216 NM)</td>
</tr>
<tr>
<td>300</td>
<td>194</td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>177</td>
<td></td>
</tr>
<tr>
<td>210</td>
<td>162</td>
<td></td>
</tr>
<tr>
<td>190</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>170</td>
<td>146</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td>137</td>
<td></td>
</tr>
<tr>
<td>130</td>
<td>127</td>
<td></td>
</tr>
</tbody>
</table>

*Table 9 – Effect of the earth curvature on the coverage respect to FL*

If the Ground Station is not at sea level the range is incremented by a fixed amount, corresponding to the “horizon” of the Ground Station itself (about 60 NM for elevation of 1000 m, 35 NM for 300 m, 20 NM for 100 m), always with the upper limit of free space range.

It is to be noted that beyond the horizon the attenuation does increase much more steeply than with the square of distance. As an example, at FL250 the horizon is 177 NM and an increase in range of 5 % causes an additional attenuation of about 7 db (with consequent loss of coverage) while a decrease of 5 % causes a reduction in attenuation of about 6 db.

**Obstacles and terrain shadowing**

The actual range in a specific site is also influenced by obstacles and terrain shadowing. The effect is not simply optical as the transmission is affected by any interference of the Fresnel ellipsoid with obstacles and terrain. Typically, for VHF and ranges from 50 to 150 NM, the transverse radius of the first ellipsoid is of the order of hundreds of meter.

The effect of partial shadowing has been duly taken into account in the coverage calculations made for MEDUP and it is to be noted that the attenuation change related to increasing interference with obstacles is very steep. Due to earth curvature, the increase in a/c range (at fixed FL) results in the increase of geometrical interference between the ellipsoid and the obstacle, giving steep increase in attenuation.
As an example, if range is limited at 100 NM by terrain shadowing with an obstacle at 30 NM from the Ground Station, an increase in range of 5% causes an additional loss of 6 dB. If the increase is 10% the additional loss grows to 14 dB.

Both effects (horizon and shadowing) explain why the link performance does fall rapidly once the limit is approached.

**Conclusions on coverage for ADS-B application**

The second criteria above (50%/12 sec) for coverage evaluation seems an acceptable basis for ADS-B surveillance and gives coverage metrics that are interesting for future exploitation. However, it should be further evaluated especially for the implications in the tracking system parameters.

However, it should be clearly stated that, possibly, for the other Data Link applications the first criteria (95%/60 sec) may be more appropriate.

The latter statement is also demonstrated by the convergence on higher values of percentage of correctly received messages, stipulated as performance limit by different known sources (LET, TLAT, CAPT, RTCA MASPS).

Another point to stress is that, for operational use at extended ranges, the siting of MGS antenna should be optimized carefully, as customarily done for radars (primary and secondary) with significant advantages in the ADS-B Ground Station case because of simpler and lighter equipment.

### 4.1.2. Coverage (ground to air broadcast applications)

#### 4.1.2.1. TIS-B (Italian MGS)

Performance of TIS-B has been evaluated taking into account the segments of routes where the continuity of ADS-B message was above 50%.

In general, continuity of TIS-B has been observed to be variable across different flight sessions.

One of the explanations of these differences is related to the number of slots usually taken by each TIS-B messages (2 or 3). This makes TIS-B transmissions intrinsically less reliable in presence of other random disturbances (no correction code is currently used).

The following table summarises the best percentages obtained for each ground station, after appropriate tuning actions.

<table>
<thead>
<tr>
<th>Ground Station</th>
<th>Rx messages/Tx messages</th>
<th>Flight (I-PIAH)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ciampino MGS</td>
<td>58%</td>
<td>Flight 2004-12-08</td>
<td>Two-slot messages</td>
</tr>
<tr>
<td>Cagliari MGS</td>
<td>48%</td>
<td>Flight 2004-12-22</td>
<td>Two-slot messages</td>
</tr>
<tr>
<td>Brindisi MGS</td>
<td>40%</td>
<td>Flight 2004-05-27</td>
<td>Three-slot message length</td>
</tr>
<tr>
<td>Padova MGS</td>
<td>15%</td>
<td>Flight 2004-06-24</td>
<td>Four-slot messages</td>
</tr>
</tbody>
</table>

*Table 10 - Best percentages obtained for each ground station*

Note: Padova MGS has provided only limited experimentation as in autumn 2004 the MGS has been installed in Maccarese site to obtain integration of Ciampino site coverage in the MFF test area.
4.1.2.2. TIS-B and other ground to air broadcast applications (Spanish MGS)

With reference to the paragraph 4.1.1.2, the “ground to air” coverage evaluated from the ADS-B messages received on board is also considered as a reference for the other “ground to air “ broadcast services.

**TIS-B APPLICATION**

The TIS-B service has been evaluated during the flight trials and the results showed a good performance of this uplink service.

The analysis has been carried out using the TIS-B management messages, which are sent every five seconds. Percentage of TIS-B management messages received from Paracuellos MGS is estimated around 95%, which shows an excellent uplink performance. The averaging period considers the time interval between the first and the last TIS-B messages received and logged on the aircraft.

The picture depicted below show the histogram of time between every two consecutive TIS-B messages sent by Paracuellos MGS. According to the slot allocation configured for this MGS, TIS-B transmissions are made every second. The time elapsed between two consecutive TIS-B messages is 1 second for the 73.44% of all the recorded TIS-B messages, in a radius of 148 NM approx.

![Histogram of time between every two consecutive TIS-B messages sent by Paracuellos MGS and received on board. Date: 21-10-04](image)

**Figure 39 - Histogram of time between every two consecutive TIS-B messages sent by Paracuellos MGS and received on board. Date: 21-10-04**

**FIS-B APPLICATION**
The reception of messages FIS-B in the different flight trials range is around to 78%.

- FIS-B transmission rate 1 message per minute and per airport

GRAS APPLICATION

As in the previous uplink services, the performance shown by GRAS is excellent, similar to the performance shown by ADS-B service.

The picture shows the histogram corresponding to the time passed between the reception on board of every two consecutive GRAS messages sent by Paracuellos MGS. With a percentage of 84.85% of received messages on board, 94.77% of these messages were logged each 2 seconds, as expected. This means that the reception was continuous and that the amount of lost messages was extremely low.

![Figure 40 - Histogram of time between every two consecutive GRAS messages sent by Paracuellos MGS. Date: 21-10-04](image)

- GRAS transmission rate 1 message each 2 seconds

ADDITIONAL INFORMATION ON AIR TO AIR ADS-B PERFORMANCE

Within the framework of the MEDUP project there was no chance for two MEDUP a/c to fly together so that air-to-air performance could be measured.

However, AENA had the chance to receive air-to-air ADS-B messages from an equipped NLR a/c during one MFF flight (21 December 2004). Reception showed excellent performance despite the long distance between the two aircraft (more than 150NM).
4.1.3. Reliability of point to point applications

4.1.3.1. Experimentation in the Italian airspace

Performance of point-to-point communications turned out to be very similar for all MGS. The following table shows the ratio between the number of successfully received messages and the number of transmitted messages for all the available flights. CPDLC message exchange was always tried when the aircraft was under ADS-B coverage.

<table>
<thead>
<tr>
<th></th>
<th>Air to Ground</th>
<th>Ground to Air</th>
</tr>
</thead>
<tbody>
<tr>
<td># transmitted</td>
<td># messages</td>
<td>Ratio B/A</td>
</tr>
<tr>
<td>messages (A)</td>
<td>logged (B)</td>
<td></td>
</tr>
<tr>
<td>3378</td>
<td>2183</td>
<td>0.65</td>
</tr>
<tr>
<td>3357</td>
<td>1001</td>
<td>0.30</td>
</tr>
</tbody>
</table>

*Table 11 - Ratio between the number of successfully received messages and number of transmitted messages*

It is evident from the table that there is a quite different behaviour of the communications in the two directions. Air to ground communication resulted much better. The explanation of this behaviour is in the still unperfect access protocol the transponders use for point-to-point communications.

To this effect it should be noted that the point-to-point protocols implemented in MEDUP are not fully compliant with the latest version of the relevant SARPS and ETSI EN’s and this may explain some of the unstable behaviour.

The previous statistics considers each VDL-4 addressed message transmitted by transponders during the flight. Due to the complexity of the application protocols, usually each dialogue between controller and pilots through CPDLC involves several VDL-4 messages to be exchanged (at least 4). In addition, those numbers also includes the automatic retransmission of messages not acknowledged by the intended recipient.

4.1.3.2. Experimentation of point to point applications with AENA

During two of the flight trials performed by AENA’s a/c, in the Spanish airspace, logon messages sent from the a/c to ground were accepted and CDPCL dialogues were successfully established with AENA’s ATM System, in Madrid. Several CPDLC messages were interchanged. Freetext messages were composed and sent by the pilots themselves.

4.1.4. Technical aspects related to User Requirements

Most flights have been performed using shadow mode ATC Centres, manned with Controllers that monitored the experimentation in parallel with those on duty in the operational ACC. At the same time, on board of the equipped a/c during demonstration flights, it has been possible to visualize on the CDTI the information broadcast from ground or transmitted point-to-point.
Operators on ground and on board were rather positive and expressed significant interest in the possible use of the MEDUP services. However, due to the limited time actually available for demonstration after all the necessary technical tuning, no deep pre-operational evaluation has been feasible.

4.1.5. Interoperability tests in flight and verifications for MFF test area

It is recalled that the interoperability tests described in Chapter 3.5 have been performed basically with the airborne equipment on ground or with the equipped a/c on ground.

It has been therefore necessary to complete those “laboratory” tests with verifications in flight.

This has been done flying with the Spanish MEDUP a/c into the service volumes of different Italian MGS and flying with the Italian MEDUP a/c into the service volumes of different Spanish MGS. Additional, very important information has been obtained during a flight of the NUP a/c in Italy because of the successful interaction with the Italian MGSs and with the Italian MEDUP a/c.

It is also reminded that some flights of the Italian MEDUP a/c have been performed with the double goal of gathering technical and pre-operational information for MEDUP and of assessing the capability of MEDUP ground infrastructure to cover adequately the MFF testing area in the Tyrrhenian sea between FL 150 and FL250. To this effect also the MFF Italian a/c and the NLR MFF a/c have flown in the last part of year 2004 exchanging data with Italian MGSs.

4.2 Data collection and analysis tools

Technical analysis of the performances achieved by datalink applications (e.g. coverage, continuity) was performed on data collected on board and on the ground during verification flights. The analysis followed the specifications stated within the Data analysis specifications document [26].

Collected data were organized in a structured way, reformatted and then processed by suitable developed software tools that computed numerical and graphical indicators.

4.3 Summary of flight trials

It is again reminded that the detailed Flight Reports (both verification and demonstration ones) are gathered in the WP 4.2 deliverable. In the present Final Report only short summaries are provided, however they provide specific notes for any significant situation.
Italian Flights

To give a feeling of the flight patterns used, reported below is a map of Italy with superimposed all the flights performed in the Italian FIR by the MEDUP a/c in year 2004

Figure 41 – Flights performed in the Italian FIR
## Italian Flights

<table>
<thead>
<tr>
<th>Date</th>
<th>Type of mission</th>
<th>Aircraft Name</th>
<th>A/C Type</th>
<th>Departure</th>
<th>Arrival</th>
<th>Length</th>
<th>Main Application Tested</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>22-01-2004</td>
<td>Test flight</td>
<td>I-PIAH</td>
<td>BE20</td>
<td>Roma (LIRA) 12:50:00 Z</td>
<td>Roma (LIRA) 15:20:00 Z</td>
<td>2h 30m 00''</td>
<td>ADS-B, TIS-B, FIS-B</td>
<td></td>
</tr>
<tr>
<td>04-03-2004</td>
<td>Test flight</td>
<td>I-PIAH</td>
<td>BE20</td>
<td>Roma (LIRA) 13:00:00 Z</td>
<td>Roma (LIRA) 15:00:00 Z</td>
<td>2h 00m 00''</td>
<td>ADS-B, TIS-B, FIS-B</td>
<td></td>
</tr>
<tr>
<td>08-04-2004</td>
<td>Test flight</td>
<td>I-PIAH</td>
<td>BE20</td>
<td>Brescia (LIPO) 08:30:00 Z Roma (LIRA) 09:55:00 Z</td>
<td>Roma (LIRA) 14:30:00 Z</td>
<td>1h 25m 00''</td>
<td>ADS-B, TIS-B, FIS-B, CPDLC</td>
<td></td>
</tr>
<tr>
<td>30-04-2004</td>
<td>Test Flight</td>
<td>I-PIAH</td>
<td>BE20</td>
<td>Roma (LIRA) 13:20:00 Z Roma (LIRA) 15:30:00 Z</td>
<td></td>
<td>2h 10m 00''</td>
<td>ADS-B, TIS-B, FIS-B, CPDLC</td>
<td></td>
</tr>
<tr>
<td>27-05-2004</td>
<td>Test flight</td>
<td>I-PIAH</td>
<td>BE20</td>
<td>Brescia (LIPM) 07:30:00 Z Brindisi (LIBR) 09:25:00 Z</td>
<td>Brindisi (LIBR) 16:04:00 Z</td>
<td>1h 55m 00''</td>
<td>ADS-B, TIS-B, FIS-B, CPDLC</td>
<td></td>
</tr>
<tr>
<td></td>
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<td><strong>Total</strong></td>
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<td></td>
<td></td>
<td><strong>3h 25m 00</strong></td>
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<td></td>
</tr>
<tr>
<td>Date</td>
<td>Type</td>
<td>Aircraft</td>
<td>Total</td>
<td>Time</td>
<td>ADS-B, TIS-B, FIS-B, CPDLC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>--------------</td>
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<td>-----------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-06-2004</td>
<td>Test flight</td>
<td>I-PIAH</td>
<td>BE20</td>
<td>Roma (LIRA) 13:35:00 Z Parma (LIMP) 16:30:00 Z</td>
<td>2h 55m 00''</td>
<td>ADSB, TISB, CPDLC, AIDC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27-07-2004</td>
<td>Test flight</td>
<td>I-PIAH</td>
<td>BE20</td>
<td>Parma (LIMP) 05:31:00 Z Roma (LIRA) 06:10:00 Z</td>
<td>0h 39m 00’’</td>
<td>ADSB, TISB, FISB, CPDLC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Roma (LIRA) 09:38:00 Z Roma (LIRA) 12:07:00 Z</td>
<td>2h 29m 00’’</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Roma (LIRA) 13:36:00 Z Parma (LIMP) 16:13:00 Z</td>
<td>2h 37m 00’’</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>5h 45m 00’’</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14-09-2004</td>
<td>Test Flight</td>
<td>I-PIAH</td>
<td>BE20</td>
<td>Parma (LIMP) 07:22:00 Z Roma (LIRA) 08:38:00 Z</td>
<td>1h 16m 00’’</td>
<td>ADS-B, TIS-B, FIS-B, CPDLC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Roma (LIRA) 10:43:00 Z Roma (LIRA) 13:46:00 Z</td>
<td>3h 03m 00’’</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td>Total</td>
<td>4h 19m 00’’</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Malta (LMML) 15:35:09 Z Roma (LIRA) 18:26:36 Z</td>
<td>2h 51m 27’’</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>Flight Type</td>
<td>Aircraft</td>
<td>From</td>
<td>To</td>
<td>Duration</td>
<td>Services</td>
<td></td>
<td></td>
</tr>
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<td>--------------</td>
<td>---------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-12-2004</td>
<td>Demonstration Flight</td>
<td>I-PIAH BE20</td>
<td>Roma (LIRA) 09:30:00 Z</td>
<td>Malta (LMML) 11:30:00 Z</td>
<td>2h 00m 00”</td>
<td>ADS-B, TIS-B, FIS-B, CPDLC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-12-2004</td>
<td>Demonstration Flight</td>
<td>I-PIAH BE20</td>
<td>Malta (LMML) 12:40:00 Z</td>
<td>Brindisi (LIBR) 15:45:00 Z</td>
<td>2h 05m 00”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>4h 05m 00”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22-12-2004</td>
<td>Demonstration Flight</td>
<td>I-PIAH BE20</td>
<td>Roma (LIRA) 10:16:00 Z</td>
<td>Madrid (LEMD) 13:40:00 Z</td>
<td>3h 24m 00”</td>
<td>ADS-B, TIS-B, FIS-B, CPDLC, AIDC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22-12-2004</td>
<td>Demonstration Flight</td>
<td>I-PIAH BE20</td>
<td>Madrid (LEMD) 16:15:00 Z</td>
<td>Roma (LIRA) 19:45:00 Z</td>
<td>3h 30m 00”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>6h 54m 00”</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>42h 32m 15”</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 12 – Italian Flights performed*
# Spanish Flights

<table>
<thead>
<tr>
<th>Date</th>
<th>Type of mission</th>
<th>Aircraft Name</th>
<th>A/C Type</th>
<th>Departure</th>
<th>Arrival</th>
<th>Length</th>
<th>Main Application Tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>04-12-2003</td>
<td>Test flight</td>
<td>EC-CHE</td>
<td>Beechcraft KingAir A-100</td>
<td>Salamanca (LESA) 08:30:00</td>
<td>Salamanca (LESA) 11:54:41</td>
<td>3h 24m 41''</td>
<td>ADS-B, TIS-B, FIS-B</td>
</tr>
<tr>
<td>04-06-2004</td>
<td>Test Flight</td>
<td>EC-CHE</td>
<td>Beechcraft KingAir A-100</td>
<td>Salamanca (LESA) 07:00:00</td>
<td>Salamanca (LESA) 11:01:13</td>
<td>4h 1m 13''</td>
<td>ADS-B, TIS-B, FIS-B, CAP, CPDLC</td>
</tr>
<tr>
<td>13-07-2004</td>
<td>Test Flight</td>
<td>EC-CHE</td>
<td>Beechcraft KingAir A-100</td>
<td>Salamanca (LESA) 07:29:56</td>
<td>Salamanca (LESA) 09:48:18</td>
<td>2h 18m 22''</td>
<td>ADS-B, TIS-B, FIS-B, CAP, CPDLC</td>
</tr>
<tr>
<td>22-07-2004</td>
<td>Test Flight</td>
<td>EC-CHE</td>
<td>Beechcraft KingAir A-100</td>
<td>Salamanca (LESA) 07:15:00</td>
<td>Salamanca (LESA) 11:50:50</td>
<td>4h 35m 50''</td>
<td>ADS-B, TIS-B, FIS-B, CAP, CPDLC</td>
</tr>
<tr>
<td>21-10-2004</td>
<td>Verification Flight</td>
<td>EC-CHE</td>
<td>Beechcraft KingAir A-100</td>
<td>Salamanca (LESA) 07:30:00</td>
<td>Valencia (LEVC) 11:54:03</td>
<td>4h 24m 03''</td>
<td>ADS-B, TIS-B, FIS-B, CAP, CPDLC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Valencia (LEVC) 14:30:00</td>
<td>Salamanca (LESA) 16:07:55</td>
<td>1h 27m 55''</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Salamanca (LESA)</td>
<td>Reus (LERS)</td>
<td>2h 10m 35''</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>07:00:00</td>
<td>09:10:35</td>
<td>5h 51m 58''</td>
<td></td>
</tr>
</tbody>
</table>

Total 5h 51m 58''
<table>
<thead>
<tr>
<th>Date</th>
<th>Flight Type</th>
<th>Aircraft</th>
<th>Departure Time</th>
<th>Arrival Time</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-12-2004</td>
<td>Verification Flight (joint to MFF)</td>
<td>Beechcraft KingAir A-100</td>
<td>Roma (LIRA) 10:00:00</td>
<td>Roma (LIRA) 14:00:00</td>
<td>4h 00m 0''</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Roma (LIRA) 10:31:46</td>
<td>Roma (LIRA) 13:21:46</td>
<td>2h 51m 46''</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>5h 02m 21''</td>
</tr>
<tr>
<td>21-12-2004</td>
<td>Demonstration Flight</td>
<td>Beechcraft KingAir A-100</td>
<td>Roma (LIRA) 08:00:00</td>
<td>Reus (LERS) 12:45:00</td>
<td>2h 58m 58''</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Reus (LERS) 10:58:58</td>
<td>Salamanca (LESA) 15:00:22</td>
<td>2h 15m 22''</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>5h 14m 20''</td>
</tr>
</tbody>
</table>

**TOTAL**  34h 28m 45''

*Table 13 - Spanish Flights performed*
5. Final considerations and Conclusions

5.1 Results of the Experimentation and User Acceptance

This Chapter will report the results of ground tests and flight trials, subdivided by application (or groups thereof) and scenario, with appropriate detail as needed for final considerations, starting from the work and documentation of WP 4.2 (already summarized in Section 4 of the present Final Report).

It will be seen in the following that MEDUP has arrived to important results in terms of technical verifications and has gathered significant experience in the preoperational testing of several Data Link Applications, but not extensively for all of the planned Applications.

To this effect it is useful to subdivide the discussion on results in different main streams, along the same line used in reporting test results within Chapter 3.3.5 and Section 4:

1. ADS-B and other air to ground Broadcast Applications
2. TIS-B and other ground to air Broadcast Applications
3. CPDLC and other Point-to-Point Applications
4. Information exchange among Ground Control Centres
5. User interest and comments

**ADS-B and other air to ground Broadcast Applications**

The application is mature, as also demonstrated by the many references in the Standardization Bodies. The range demonstrated (of the order of 150 NM even with transponders not with the most updated design configuration and not optimized siting) is a good starting point for the evaluation of wide area implementation as complement to secondary radars or for autonomous coverage in non radar areas.

It should be also considered that the Data Link enables not only a/c 3D position transfer to ground but may enable additional information transfer in terms of speed, track and intent in a way most similar to Mode S Radar Enhanced Surveillance and this in areas like the Mediterranean one where Mode S Radar will not be widespread in a foreseeable future. This additional information may in turn enable better ATM functions (MTCD, AMAN, DMAN, etc).

**TIS-B and other ground to air Broadcast Applications**

TIS-B has proven to be reliable to a range from 100 to 150 NM and so have other ground-to-air applications (FIS-B, meteo now-casting, etc).

TIS-B, which means uplink of radar derived data surveillance, needs both real time and assurance of completeness (any lacking track may be a critical one) while other applications may accept reasonable latency. In this respect it is to be noted that other data links (from ACARS to VDL-2) provide air-ground connection only and cannot assure real time service.

Further consideration should have been given to the actual operational value of real time availability of the different ground-to-air applications. Such consideration has not been feasible involving users within the time frame of MEDUP for several reasons, some of which will be reported at the end of this paragraph as they have influenced also the other issues in the list above.
CPDLC and other Point-to-Point Applications
As reported in paragraph 4.1.3 above, the experimentation brought somewhat unstable connection and a less reliable one from ground to air than from air to ground
A possible explanation for this behaviour is in the still unperfect access protocol that the transponders used for point-to-point communications. To this effect it should be noted that the point-to-point protocols implemented in MEDUP are not fully compliant with the latest version of the relevant SARPS and this may explain some of the unstable behaviour.
As for TIS-B, however, a more complete evaluation of performance has not been feasible within the time frame of MEDUP.
From a more wide viewpoint, it should also be mentioned that most of the CPDLC messages lend themselves to be handled by a non real time data link such as VDL-2, already planned for implementation within some ECAC states.

Information exchange among Ground ATC Control Centres
All the necessary ISDN/IP connections between MGS and Shadow Mode ATC Centres have been correctly established, so that any one MGS could be able to communicate with each other (when needed with unicast and multicast protocols) through the Shadow Mode ATC Centres. The connection has been extended without problems to Eurocontrol Experimental Centre Bretigny into their AVT and to DFS in their Langen site, enabling also connection with the NUP network.
The test also covered the verification of the Domain Name Service (DNS) for translation between hostnames and IP addresses.

User interest and comments
The user involvement has been possible, as several flights have been performed using shadow mode ATC Centres, manned with Controllers that monitored the experimentation in parallel with those on duty in the operational ACC. At the same time, on board of the equipped a/c during demonstration flights, it has been possible to visualize on the CDTI the information broadcast from ground or transmitted point-to-point.
Operators on ground and on board have expressed significant interest in the possible use of the MEDUP services. However, due to the limited time actually available for demonstration after all the necessary technical tuning, no deep pre-operational evaluation has been feasible.

Limited time available for demonstrations
The operational experimentations performed within 2004 were not exhaustive for several of the original objectives, mainly because the demonstration flights were flown only for a short period of time when all the necessary Hardware/Software had been made available.
In turn the delays were originated by different causes, among which:
- Delays in obtaining no hazard certification of the Italian a/c for installation of MEDUP equipment; hence delay of actual availability of equipped a/c.
- Difficult alignment of CDTI S/W specifications between MFF and MEDUP because of similar requirements but not identical ones. Hence the CDTI S/W, and consequently parts of MGS operational S/W, were available in many different successive releases with delay for the final ones.
- The choice of different transponder vendors caused additional work to provide interoperability requirements and subsequent verifications. The corresponding delay did however bring finally a positive result in terms of interoperability checks (cfr Chapter 4.1.5 and Paragraph 3.3.5.3-Interoperability Tests).
5.2 Safety and economical issues

This Chapter will consider preliminary the safety and economical issues. Both issues are of great interest for the Partners and for all the stakeholders and are more or less interlaced with the institutional issues covered in Chapter 5.3 below.

In fact, the initial safety discussion (reported in paragraph 5.2.1-Safety considerations) considers mainly the hazards, mitigations, etc as related by the use of ADS-B using the VDL-4 Data Link and examines the causes of such hazards as due to the different domains (space, airborne, ground).

In addition to that discussion, Chapter 5.3 Institutional issues will then consider the new pattern of tasks distribution, shared by space segment, communications segment, airborne segment, ATS segment.

The economical issues (reported in paragraph 5.2.2 -Economical issues below) will consider the problem of investment costs, including estimates for airborne systems, installation and certification costs and the associated costs for the ground segment. The rough estimate of Costs versus Benefits is related to the air transport world considered as a whole.

Again, additional considerations on economical regulation issues will be examined in Chapter 5.3 Institutional issues as, for example, the issue on new computations for the flight taxes because costs are shared between users and service providers in different ways with respect to benefit share.

5.2.1-Safety considerations

The objective of the high level synthesis for safety considerations in the ADS MEDUP project is to highlight the major hazards and the new pattern of tasks distribution shared by all segments (airborne, ATS, space, communication). This analysis is mainly based on the consolidation of existing safety assessments of related operational concepts instantiated on the MEDUP concept.

The scope of this safety consolidation for ADS-MEDUP is captured with the intended usage of the following operational applications:

- ATC surveillance in non-radar area: provision of “Radar-like” services in an environment where ADS-B separation minima replace procedural separations for ADS-B equipped aircraft
- ATC surveillance in en-route and terminal areas: provision of “multiradar”-like separation minima with radar augmented by ADS-B

The new pattern of responsibility is captured relatively to the following segments: space, communication, airborne and ATS segments with the ADS MEDUP specific architecture consisting of the ground network, the ADS-B ground station and the ATM communications server.

The ADS-MEDUP safety assessment consolidates the results of safety assessments from related projects. However, each of these safety assessments has its own "specific approach" in terms of: application modelling, methodology, hazard classification scheme and analysis of elementary causes.

The attitude adopted in the MEDUP safety process is to observe a conservative approach. The hazard severity is assigned considering the most stringent effects in the most challenging phase or operation considered. Therefore, MEDUP safety assessment is probably over-conservative and any local implementation would have to refine the effects of local hazards and the mitigation means.

The following six hazards have been considered for each application:

- Loss of ADS-B information for one/all (or multiple) aircraft,
- Corruption of ADS-B information for one/all (or multiple) aircraft,
- Possible degradation of ADS-B information for one/all aircraft.

Analysis for ATC surveillance in non radar area and ATC surveillance based on radar and ADS-B can be summarised as follows:
• There exists some variation in the assigned severity levels for similar hazards across the various safety assessments, in relation to differences in intended operations or interpretations of the operational context.
• The majority of the hazards, when they are detected, have a "major" severity.
• The majority of the non detected hazards are of "catastrophic" severity. These hazards are related to erroneous ADS-B information.

Predictive safety assessment results on the impact of loss of surveillance and corrupted surveillance cross-compare with operational issues voluntarily reported for radar surveillance. Poor quality of surveillance negatively impacts the ATCO performance. Issues related to the loss of surveillance information or erroneous targets are reported as "safety related problems" by controllers.

The elementary causes associated to the hazards have been allocated to each domain as summarised below.

*Space domain*: Elementary causes are due to signal in space failures and GPS satellites failures. Such causes are likely to constitute common cause failures affecting multiple aircraft.

*Airborne domain*: The elementary causes are induced by either the ADS-B system failure or malfunction (with the caveats that there is no clear definition of the ADS-B system) or the navigation and altitude source providing the information to be conveyed within ADS-B messages. It shall be reminded that elementary causes concern the ADS-B out function only.

*Ground domain*: This constitutes the majority of the causes. The main causes are due to failures or malfunction of ground components: ground sensors, ground stations, ground communication systems, ground processing system and ground ATC display. Several functions (not specific to a component) may also generate some hazards: integrity check, validity check, parity check and quality check. The failures of the site monitoring may also induce hazards.

*Communication domain*: This segment is considered separately as a potential for increasing the severity of identified hazards when a failure occurs and is combined with other hazards. Causes are either related to failure of the ground or the airborne communication system or the congestion of the communication means.

The following tables summarise the major operational hazards identified and their corresponding analysis for ATC surveillance in non radar area and ATC surveillance using radar and ADS-B.

---

3 see e.g. ASRS (National Aviation Safety Data Analysis Center [http://www.nasdac.faa.gov/]) #558781
4 see e.g. ASRS #558834
<table>
<thead>
<tr>
<th>Operational hazard</th>
<th>Technical failure condition</th>
<th>Severity</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of ATC surveillance in non-radar areas</td>
<td>Loss of ADS-B information for one aircraft</td>
<td>Minor impact if detected (likely to be detected) Severe impact if not detected</td>
<td>Similar contingency procedures as for total loss of radar information in a radar covered area (PANS-RAC 4444 part IV par. 8.4). Low traffic density enabling reversion to contingency procedures</td>
</tr>
<tr>
<td></td>
<td>Loss of ADS-B information for all aircraft</td>
<td>Always detected, but major impact</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Requirements for control/mitigation of hazards</td>
<td>• Definition of appropriate contingency procedures • Procedures and training complying with &quot;ICAO separation and Airspace Safety Panel: Operational use of ADS-B in non radar airspace - Generic design safety case&quot; • Procedures to transition from non ADS-B areas to ADS-B areas • Minimum requirements for airborne, ground and communication systems</td>
<td></td>
</tr>
<tr>
<td>Errorneous ATC surveillance in non-radar areas</td>
<td>Corruption of ADS-B information for one aircraft</td>
<td>Minor impact if detected Catastrophic impact if not detected</td>
<td>Similar contingency procedures as for total loss of radar information in a radar covered area (PANS-RAC 4444 part IV par. 8.4). Low traffic density enabling reversion to contingency procedures</td>
</tr>
<tr>
<td></td>
<td>Corruption of ADS-B information for all aircraft</td>
<td>Major impact if detected Catastrophic impact if not detected</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Requirements for control/mitigation of hazards</td>
<td>• Same as for those to mitigate the loss of ATC surveillance in non-radar areas • Display of misleading ADS-B information to ATCO or pilot without appropriate warning shall be remote • Minimum integrity requirements on the broadcast and display of ADS-B information</td>
<td></td>
</tr>
<tr>
<td>Degraded ATC surveillance in non-radar areas</td>
<td>Degradation of ADS-B information for one aircraft</td>
<td>Major impact if detected Catastrophic impact if not detected</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Degradation of ADS-B information for all aircraft</td>
<td>Major impact if detected Catastrophic impact if not detected</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Requirements for control/mitigation of hazards</td>
<td>• Same as for those to mitigate the risk associated to erroneous ATC surveillance in non-radar areas • Minimum requirements for availability, continuity of service and accuracy of ADS-B information</td>
<td></td>
</tr>
</tbody>
</table>

Table 14 - Summary of hazards for ATC surveillance in non radar area
<table>
<thead>
<tr>
<th>Operational hazard</th>
<th>Technical failure condition</th>
<th>Severity</th>
<th>Assumptions</th>
</tr>
</thead>
</table>
| Loss of ATC surveillance using radar and ADS-B | Loss of ADS-B information for one aircraft | Major impact if detected  
Severe impact if not detected | None |
| | Loss of ADS-B information for all aircraft | Always detected, but major impact | • As an emergency temporary measure, use of flight levels spaced by half the applicable vertical separation minimum  
• ADS-B is not a sole means to provide tactical control |
| | Requirements for control/mitigation of hazards | • Definition of appropriate contingency procedures and training  
• Minimum requirements for airborne, ground and communication systems, including warning on the loss of ADS-B information |
| Erroneous ATC surveillance using radar and ADS-B | Corruption of ADS-B information for one aircraft | Major impact if detected  
Severe impact if not detected | |
| | Corruption of ADS-B information for all aircraft | Severe impact if detected  
Catastrophic impact if not detected | |
| | Requirements for control/mitigation of hazards | • Same as for those to mitigate the loss of ATC surveillance using radar and ADS-B  
• Display of misleading ADS-B information to ATCO or pilot without appropriate warning shall be remote  
• Minimum integrity requirements on the broadcast and display of ADS-B information |
| Degraded ATC surveillance using radar and ADS-B | Degradation of ADS-B information for one aircraft | not assessed | |
| | Degradation of ADS-B information for all aircraft | not assessed | |

Table 15 - Summary of hazards for ATC surveillance based on radar and ADS-B
5.2.2 -Economical issues

This paragraph considers the economical aspects of the ADS-MEDUP Programme and explores the issues that will need to be addressed when undertaking a full economical assessment.

The purpose of the economical assessment should consider:

- estimates of the implementation costs to be incurred;
- high level assessment of the benefits that are expected to arise from the ADS-MEDUP services in solving current and potential operational difficulties in the ADS-MEDUP area; and
- allocation and possible sharing of costs and benefits between users and service providers.

As a first step airlines will be considered together as a single stakeholder and an assessment will not be made of the costs and benefits for particular airlines.

The benefits assessment will be made for different percentages of aircraft equipage. The time frame selected is 2010 - 2015, which is consistent with the assessment year being used by the Mediterranean Free Flight (MFF) Programme. This choice is based on the fact that the operational benefits analysis should be based on a timeframe when most of the MEDUP applications may be considered as mature.

Additional information and references are reported in Economical consideration in the ADS-MEDUP programme [27].

5.2.2.1-Traffic Statistics

Projected traffic volumes in the ADS-MEDUP area are required for 2010, using the same time projection as in MFF Project. Taking CFMU traffic data for a representative day in 2004 and applying the annual growth rates for each traffic flow from STATFOR have built this. In order to achieve a conservative estimate of benefits, the base STATFOR forecast should be used.

The representative day will be chosen with the same method used in MFF Programme (refer to EEC-xxx)

5.2.2.2-Fleet Composition

The MFF Programme has carried out a detailed analysis (refer to Economical consideration in the ADS-MEDUP programme [27]) of the expected distribution of aircraft types in the MFF area in 2010. This has considered the aircraft types currently using the MFF airspace and has made some assumptions about how those aircraft types might be substituted in 2010, in whole or in part, with more modern aircraft.

For these preliminary considerations it will be assumed that the mix of aircraft types is currently similar in both the MEDUP and MFF areas and hence that the MFF analysis provides a good estimate of the aircraft types that will use the MEDUP airspace in 2010.

The following chart is extracted from Economical consideration in the ADS-MEDUP programme [27]. It covers the 20 most common aircraft types, which account for 80% of the traffic.
5.2.2.3- Services/Applications

The services/applications to be considered are:
- ADS-B for en-route, terminal and surface air traffic control. This service/application will enable the aircraft to broadcast relevant flight data and will support improved separation assurance, automatic downlink of airborne parameters and notification of the short term intent of an aircraft. Other MEDUP services/applications air to ground broadcast will also be considered.
- TIS-B with airborne display of traffic (CDTI). This service/application concerns the transmission of the radar traffic situation to a pilot. Other MEDUP services/applications ground to air broadcast will also be considered.
- The flow of information throughout the ADS-MEDUP network as foreseen by the different point-to-point MEDUP services/applications. This will provide advance knowledge about flights, including expected arrival times, to all linked ACCs and other useful information.

5.2.2.4-Equipage

Overall benefits will depend on the percentage of aircraft equipped with the required technology. The relationship between total realisable benefits and the percentage of equipped aircraft is expected to be non-linear, and future aircraft equipage is uncertain. Incentives may be necessary to encourage the early installation of airborne equipment.

The approach taken to equipage will be to consider the costs incurred and the benefits realised from different percentages of equipped aircraft in 2010 - 2015. Increments of 10% will be used. This approach will allow an assessment to be made of the minimum percentage of equipped aircraft to justify the costs incurred.

The fleet composition analysis will identify the number of new aircraft that will be introduced after 2010. If it can be assumed that all new aircraft will be supplied with the necessary technology to support the ADS-MEDUP applications after some year in the range 2010 - 2015, a minimum value may be found for the percentage of aircraft that will be equipped in specific year. Any retrofit on existing aircraft (with adequate residual life) will increment that minimum value.

5.2.2.5-Infrastructure

An Eurocontrol CBA for ADS-B applications (refer to Economical consideration in the ADS-MEDUP programme [27]) assumed a coverage radius of 60 NM and estimated that 525 ground stations would be required for the whole of ECAC.
According to the MEDUP flight trials a coverage radius of 150 NM on the average may be assumed with appropriate siting design.

This implies a reduction factor of about six, bringing the total number down to about 90.

Using a rule-of-thumb assumption that the Mediterranean area accounts for around one third of the total ECAC area, the number of ground stations required in the ADS-MEDUP area can be preliminary estimated to be around 30.

5.2.2.6-Costs

Ground infrastructure costs per site may be estimated as follows:

- Equipment, infrastructure, tests: 450,000 €
- ATC system SW, training of Controllers: 100,000 €
- Maintenance (on equipment), ground communications (per year): 45,000 €

Aircraft equipage costs (including installation, certification, pilot training):

- Transceiver for new a/c: 140,000 €
- Transceiver for retrofit: 240,000 €

Note: the order of magnitude of these costs is derived from Package 1 Surveillance Applications CBA (Cost Benefit Analysis of Package 1 Surveillance Applications enabled by ADS-B, Volumes 1 & 2, EUROCONTROL, Edition 0.B4, 21 Jun 2004). These costs would have to be further validated and updated with technology maturity and market.

These costs are aggregated as follows:

For equipment, infrastructure, tests:
- Sensors and antennae: 260,000 € (updated from ADS-B CBA with recent cost estimate from various CBAs)
- Infrastructure: 170,000 €
- Equipment acceptance test: 2,000 €
- Site acceptance test: 13,000 €

Total rounded to 450,000 €.

For ATC system SW, training of Controllers:
- ACC upgrade cost: 45,500 €
- CWP: 38,500 €
- Training: 16,000 €

Total rounded to 100,000 €.

For maintenance and ground equipment (per year):
- communication link: 19,700 €
- Maintenance: 23,400 € (9% of acquisition cost of 260,000)

Total rounded to 45,000 €.

Aircraft equipage costs are re-used from Package 1 Surveillance Applications CBA (Cost Benefit Analysis of
5.2.2.7-Benefits

Benefits that might be obtained from ADS-MEDUP are:

- Possible reduction in longitudinal separation in some areas out of radar coverage currently out of radar coverage (such as North Africa) as a result of substitution of procedural control, where now implemented, with radar-like control provided by ADS-B.

- Advance knowledge about the en-route arrival time of flights in ADS-MEDUP sectors reflecting the airborne experienced conditions, achieved by placing ground stations in parts of North Africa and providing ground-to-ground communications links between ACCs. This will allow pre-planning and will avoid en-route delay.

- Better sharing of workload between controllers and pilots and better decision making since a pilot will see similar information based on the same source of data that is available to a controller and will be able to suggest actions that could be taken to resolve potential conflicts. This will reduce controller workload.

- The avoidance of expenditure on the replacement of radar stations that are at or near the end of their life. In addition VDL Mode 4 stations provide better redundancy and greater positional accuracy than secondary radar.

- TIS-B is a means whereby conventional surveillance infrastructure can be used to broadcast the position of non-ADS-B equipped aircraft to those that are equipped and hence allows flight crew to be provided with improved situational awareness. It supports transition to ADS-B and enables some benefits to be realised by aircraft operators when they equip. Improved awareness of traffic information and better decision-making are the main benefits.

5.2.2.8-Incentives

Economic analysis can be used to consider the economic viability of ADS-MEDUP from the viewpoint of each participating stakeholder, and for the programme as a whole by aggregating stakeholder costs and benefits. When making the aggregation, the financial flows between stakeholders need to be understood to avoid any double counting of costs and benefits.

The following diagram shows the service and financial flows between the principal stakeholders.

![Service and financial flow between stakeholders](image_url)

Most ANSPs and many airport operators use cost recovery systems, where charges, fees and taxes are calculated in such a way as to cover the complete cost of service provision.
The key to gaining acceptance of a worthwhile project is to ensure that the costs and benefits are shared between the stakeholders on an acceptable basis.

In addition, although there may be an economic case for investment by all members of a particular stakeholder group, the case may be stronger for a member who invests later than other members since the benefits available will increase with the number of members that have made the investment. Provided that the anticipated benefits are likely to be achieved, the earlier members invest, the greater will be the total economic benefit over the assessment period. On the contrary, some benefits could be partially reduced if some services had to be limited because of lack of equippage.

Economic incentives may, therefore, be necessary to:

- encourage each type of stakeholder to invest by switching costs and benefits between stakeholder groups;
- encourage early investment by all stakeholders to maximize the total benefits that are available over the assessment period;
- discourage members of a stakeholder group from delaying investment by switching benefits from members who invest later to those who invest earlier.

The means of switching costs and benefits, and hence providing the necessary incentive, could be provided by a third party such as the EC or could be reflected in differential charges so that, for example, an equipped airspace user receives a reduction in the unit charge and a non-equipped user pays more. If sufficient incentives can be created by setting up mechanisms that have the effect of switching money from one stakeholder to another, no additional monetary benefit is being created across the programme and the cost to the EC (or other body) over the assessment period would be zero.

The following chart shows how a differential charging system might operate for different percentages of equipped aircraft given that the total route charges collected should be a constant amount.

![Percentage of equipped aircraft chart](image-url)

**Figure 44 – Percentage of equipped aircraft**

As the percentage of equipped aircraft increases, the total discounts provided also increase and have to be recovered from a reducing number of unequipped aircraft. To avoid penalties paid by unequipped aircraft becoming excessive, the discount percentage offered would have to be reduced as the percentage of equipped aircraft increases.

For example, if the penalty should be no more than 5%, it can be seen that a 10% discount could be offered until equipage is 32%, reducing to 7% until equipage is 40%, reducing to 5% when equipage is 50%, etc.
5.3 Institutional issues

When dealing with the institutional issues connected to possible large scale adoption of applications enabled by a high performance Digital Data Link (with capability to support real time applications) the following points should be duly addressed:

1) The network infrastructure has an implementation that is spread in different States in the area and hence the responsibility is shared and has to be co-ordinated and regulated (having in mind the different institutional regulations – Eurocontrol, ECAC, non ECAC and the more global ICAO policies).

2) Liability should regard many different aspects (safety, performance, ground connection, AIS/AIP alignment, security, etc).

3) The share between service providers and airspace users of the implementation costs may be quite different with respect to e.g. conventional radar surveillance means. Also, not all airspace users and not all service providers may be able to take full advantage of the information made available through the network, hence a problem for cost recovery.

4) According to Eurocontrol/ECAC policies, the different applications should be grouped appropriately, also in terms of possible timescale for operational implementation.

In the following paragraphs, the above points will be discussed, together with due reference to applicable Documents.

5.3.1 Share of Responsibility

The problem of shared responsibility among States has been present in Civil Aviation since a long time. In most cases (regarding basically two States with common boundaries) it has been solved by bilateral Letters of Agreement.

More recently and specifically for infrastructures of worldwide character (as the Satellite Navigation System), ICAO has addressed the issue in its different aspects (operational, technical, legal, cost recovery). In this respect, at the 35th General Assembly 2004, a good overview of the legal aspects is given in WP 75, Report on the establishment of a legal framework with regard to CNS/ATM systems including GNSS (Agenda Item 36 of the General Assembly).

The main results of the Report and of its Attachments are summarised below.

First of all, the Report recalls full validity of the Statement of ICAO Policy on CNS/ATM Systems Implementation and Operation in its 1996 release (enclosed as Annex 5.1 to the present Final Report, because of its relevance). The Statement stresses the importance of common use and of collaboration in CNS/ATM Systems including GNSS. This would apply entirely also to Data Link and the relevant Applications.

The Report recalls also, with specific reference to GNSS characteristics, to the resolution of the 32nd Assembly on the Charter on the Rights and Obligations of States Relating to GNSS Services (also enclosed as Annex 5.2 to the present Final Report, because of its relevance).

Other statements regard (quotations in italics):

• Obligations of the ICAO States: in implementing GNSS, a Contracting State should satisfy itself that the following comply with the relevant ICAO SARPs: (a) the signals-in-space; (b) its own
implementation facilities; and (c) the equipment and procedures of operators.

- Certification: In accordance with their responsibility under Article 28, States providing signals-in-space, or under whose jurisdiction such signals are provided, should certify the signals-in-space by attesting that they are in conformity with the ICAO SARPs, and the State having jurisdiction under Article 28 should ensure that avionics, ground facilities and training and licensing requirements comply with the ICAO SARPs.

- Cost recovery: Article 5 allows the GNSS signal provider to establish a cost recovery mechanism for the purpose of recovering the cost of such services from the users of GNSS signals. It was suggested that such mechanism shall ensure the reasonable allocation of costs among civil aviation users themselves and among civil aviation users and other system users, in view of the current statistics that aviation users only amount to a small percentage of the users of the signals.

- Issues relating to communications: The use of communication satellites, as compared to the use of terrestrial systems, did not present any new legal issues at the current stage. The disclaimer clause was almost universally used. It was the air traffic service providers’ responsibility to arrange redundancy of communication services to satisfy the requirements relating to reliability, availability and continuity of the services. On the other hand, in the light of further experience with CNS/ATM, and if deemed necessary and opportune, the issue of the limitation of liability in communication services could be further studied in the future.

- Issues relating to surveillance: It was noted that, since surveillance was linked to both communications and navigation, the legal framework for this activity would largely depend upon the legal regimes applicable to these latter two elements of CNS/ATM systems. It was further observed that, since surveillance would depend more on automated systems, a shift of focus from human error liability to the equipment manufacturers’ liability could be expected. However, no separate legal issues regarding surveillance, which may need to be addressed at this stage, were identified.

It should be noted that several of the above statements refer to GNSS, but they can easily expanded in principle to other CNS/ATM Systems with widespread implementation. It should be further noted that ICAO regulations apply to all States, which did sign the Chicago Convention. In this frame, the position in Eurocontrol or ECAC is not so much relevant.

Additional and important institutional references are the SES (Single European Sky) regulations, approved one year ago by the European Council.

5.3.2 Overview of aspects for operational use

As reported above in item 2, the system has to cope with different criteria to be used with full operational capability and again this is a matter of responsibility.

The main one is Safety. For this item and specifically for examination of risks and hazards related to the operational use of innovative CNS/ATM tools and procedures, Eurocontrol has issued the regulations ESARR 3 and ESARR 4 which are easily obtained from the Eurocontrol site. These regulations guide the way on how to introduce new CNS/ATM systems (ESARR 3) and how to assess their effect on safety both in quantitative and qualitative manner (ESARR 4). For distributed systems the overall safety can only be assured using same (or very similar) criteria in different States. An overview of Safety issues related to MEDUP Applications is provided in Chapter 5.2 above.

Performance is expressed by several items such as accuracy, continuity, availability, coverage (or better operation volume). All the above parameters are expressed differently in dependence of the specific application being considered. Actually, most of the relevant parameters are considered in ICAO Annexes and Regulations as well as in documents of other Standardization Bodies (Eurocontrol, EUROCAE, FAA,
RTCA, etc). An overview of Standardization in force is provided in Paragraph 3.1.2.2 of the present Final Report. Moreover, discussion on actual performance verified and assessed in MEDUP experimentations, both technical and pre-operational, is provided in Paragraph 3.3.5 and in Section 4.

**Ground connections** between Ground Stations and with ATC Centres provide the necessary information exchange to fully exploit the operational capability of the air-ground Data Link as enabler of applications/services. However, independently of the actual carrier, this amounts basically to an ISDN connection which can easily complied with.

Somewhat correlated to the connection among Centres, is the issue of interoperability and seamless operation. This issue has been covered in the WP 009 for the 11th ICAO ANC (Air Navigation Conference) prepared by the ICAO Secretariat and giving definitions for the two terms as follows.

*Interoperability* within the ATM system may be described as the ability to transfer information or effect functionality across any discontinuity, in order to enable operations and it concerns mainly the system operators.

*Seamless* within the ATM system may be described as the property that allows a transition across any discontinuity which, from the perspective of the transiting agent, does not require a considered action to facilitate the transition. It concerns mainly the Airspace users. It should be noted that, in this context, seamless does not imply ATM systems convergence into singleness.

As a consequence, the global ATM system should be interoperable in all cases, and seamless wherever and whenever possible.

The WP is enclosed as Annex 5.3 being of relevant reference.

**AIS/AIP** alignment is another important issue when passing from experimentation to operational use but it may well be considered absorbed in the overall effort of harmonization of AIS/AIP (already in progress in Europe).

**Security** is of paramount importance for the time being. Although connected in general with safety, security has also its own separate criteria and should be considered with great attention. In this respect ECAC States have presented to the 35th ICAO General Assembly the WP 145 on Agenda Item 14: Aviation security. The WP (ATM related security initiatives in Europe) provides information about the European bodies working on the matter (ground and airborne provisions, connection with the military) and is enclosed as Annex 5.4 to the present Final Report.

### 5.3.3 Cost recovery

Cost recovery presents two separate problems, the first being related to the route charges and the second being related to possible balance among ANSPs.

The first problem arises from the comment by the airlines, observing that e.g. to provide ADS-B the a/c have to implement equipment on board, with the related costs. On the contrary, the ATM service providers obtain surveillance and also other additional useful information at reduced cost (e.g. compared to radar). Hence, some form of balance has to be foreseen when defining the route charge levels, which may well be differentiated among the different airspace users, according to their actual equipage. Moreover a direct cost reduction would possibly incentive costly equipage, as the operational benefits for equipped a/c may not be sufficient.

An interesting paper on this is the AP/ACG/20/6 of 29.4.03 by Eurocontrol (enclosed as Annex 5.5). In that Paper economic incentive by reduction of route charge is investigated, as an alternative to mandate, with the objective to incentive early equipping of the a/c with new ATM/CNS equipment (in that case it was related
to Link 2000+). An example is described in which the reduction (2%) for equipped a/c would be compensated by an increase (very small until the equipped a/c are a small percentage of the total).

The point of cost allocation is also covered in WP 155 of the 35th ICAO General Assembly, prepared by the Netherlands on behalf of the European Community. In that Paper reference is mainly to GALILEO with paragraphs 3.1 and 3.2 covering cost allocation (also between civil aviation users and other users) and legal framework.

A general overview on ATM/CNS systems and services in the ongoing process of commercialisation is available in the Report WP 10 of the 35th ICAO General Assembly and namely in the Chapter 3 (Implementation of a Global Navigation System). Chapter 3 of WP 10 is reported as Annex 5.6 to the present Final Report. It may constitute a reference for the second problem quoted at the beginning of this sub-paragraph.

Of course several of the consideration made so far on the cost issue are further discussed in Chapter 5.2 Safety and economical issues and Chapter 5.5 Exploitation Plan.

### 5.4 Expansion to non-ECAC States

Reference is made to the preliminary results of WP 5.4 of sub-Phase A2 and also of WP 5.2 of Phase B.

It aims to give an appropriate development of the following issues:

1. The start of formal contacts with non ECAC States (Southern and Eastern borders of Mediterranean) in order to show the results of ADS-MEDUP and to plan possible, future involvement to complete coverage in terms of infrastructure and to exploit the MEDUP applications for the benefit of air transport in those States and consequently in the whole Mediterranean Area.
2. The institutional relevance of the diffused nature of the infrastructure use and the related responsibilities of States and international entities in assuring the correct ATM service to all users (including the issues of airspace organisation and flight procedures).

The latter issue is however, adequately covered by the discussion in the preceding Chapter 5.3 Institutional issues. Therefore the present Chapter is devoted mainly to report actions on item 1 above.

The actions are listed in a geographical sequence from West to East.

- In the frame of Sub-phase A2, AENA undertook actions towards Morocco and Algeria, taking advantage of existing co-ordination initiatives like AEFMP Programme (Regional Harmonization Programme with participation of Algeria, Morocco, France, Portugal and Spain).

  AENA presented to Moroccan and Algerian representatives the following main issues:
  - general information on ADS and its benefits
  - the ADS in Spain: different fields of experimentation, plans and objectives
  - activities performed in the Mediterranean basin under the MEDUP project, including the technological framework, the equipment installed, the trials already performed in Spain and those expected to be performed in Italy.
  - reference to the applications of ADS-B being validated in the Mediterranean basin under the context of MFF
  - broader view of ADS activities in Europe, including other EC projects

  As a first reaction, Morocco and Algeria found ADS activities performed in Spain (and, in general, in the Mediterranean basin) of great interest to them, and they would like to be kept updated.

  Regarding their plans, the main conclusion extracted from the contacts established with Morocco and Algeria in the context of MEDUP is that, in general, both countries are more interested in new concepts and technologies once they are in the stage of being operationally implemented.

- ENAV has formally contacted by letter the Tunisian CAA and the Egyptian CAA. Both these CAAs
are already in contact with ENAV for different matters, including briefing on current Studies and pre-operational testing. A more detailed action plan has not been established yet. A further contact has been started with the Turkish CAA.

ENAV will start to establish appropriate contacts with the Libyan CAA, taking advantage of the recent withdraw of the embargo and the restart of commercial flights to and from Libya.

In order to cover formally the involvement of several States in Africa, ENAV took the action to inform the ICAO African Region Office about MEDUP and about the possible contacts with States that could be interested in MEDUP knowledge and possible exploitation.

- HCAA has made extensive contacts with the various relevant Agencies in the State of Cyprus, mainly with the Civil Aviation Division (within the Ministry of Transportation & Public Works) and with the Air Navigation Services (within the Cypriot Telecommunications Authority).

Detailed presentations have been provided to the Cypriot experts regarding all aspects of the MEDUP Programme:

- The ADS concept.
- The infrastructure (ground stations, interfaces etc.).
- The avionics (CDTI etc.).
- Expected operational benefits (including an extensive introduction to MFF).
- Financial considerations.
- Future concepts.

The show of interest from the Cypriot side was rather encouraging. Thus, further contacts have been discussed including a possible visit (with an appropriate “in situ” presentation) to the Monastery Ground Station by a delegation of Cypriot experts.

In general, it can be concluded that on the specific item of “Expansion to non-ECAC Mediterranean States” several information actions have been started but to date none brought to actual involvement of other States. Some slowing down of those actions may be related to the situation about data link technology described in the following Chapter.

In this connection, reference may be made to the following Chapter on “Exploitation Plan” where further, more focused initiatives are envisaged towards pre-operational experimentation of Data Link applications, possibly with Multi-Link solutions.

### 5.5 Exploitation Plan

Taking into account all considerations in the previous Chapters in this Section 5, it is possible to outline the Exploitation Plan, considering the MEDUP Programme activities as an investment that the European Commission and the MEDUP Partners have made, and actually a significant one.

However, the Exploitation Plan should not be considered as self-standing, stemming only from MEDUP Programme. It should, instead, fit appropriately into a wider scenario, including the more recent developments of European Policies in the Air Transport world.

This broader view has been already implicitly and/or explicitly considered in Chapter 5.2 Safety and economical issues), Chapter 5.3 Institutional issues), Chapter 5.4 Expansion to non-ECAC States).
The major points in this broader view include:

- The Single European Sky, which is now law of the European Union, which is now wider than only few years ago
- The concept of Co-operative ATM
- The concept of more integrated CNS
- Stakeholder involvement
- Security issues
- Unified and restructured Eurocontrol Programmes
- Gate-to-gate approach
- High economic pressure on airspace operators
- Minor Airports
- Data Link technology

The latter issue is of paramount importance for MEDUP Exploitation Plan and deserves further clarification. Recently, Eurocontrol and FAA, backed by a/c manufacturers and by most airlines, did choose 1090 Extended Squitter as the near-mid term technology for real time Data Link applications and specifically for ADS-B and other air to ground broadcast applications.

Among other reasons, this choice was supported by the fact that 1090 Mode S Enhanced Surveillance Transponders, predicated to be a standard (at least de-facto) for commercial a/c operating in Core Europe in the next future, may enable 1090 Extended Squitter operations with minor modifications.

Together with the lengthy standardization process, the above fact will reduce the willingness of airlines to equip early with VDL-4. Another drawback for VDL-4 is the already planned use of VDL-2 for non time-critical air-ground Data Link. In fact VDL-2 and VDL-4 may show critical interferences on board and would require appropriate and careful assignment of VHF frequencies and/or the availability of new generation multimode transceivers (software radios).

The different points outlined at the end of Chapter 5.4 Expansion to non-ECAC States, do influence the MEDUP Exploitation Plan, together with the specific characteristics of Mediterranean area, as summarized in paragraph 3.1.1

With all this in mind and coming back to the different steps of development/complement of MEDUP, several lines have been envisaged and are described in the following.

**A first line** is to complete any outstanding technical investigation about performances of VDL-4 Data Link and especially to compare them with the performances of 1090 Extended Squitter Data Link, both in theoretical as well as in practical environment, taking into due account the specific conditions prevailing on the Mediterranean Area (reduced SSR pollution, presence of large sea areas, etc).

**A second line** is of more operational character, including additional pre-operational experimentation (with more extensive operator involvement) and taking into account the frame of the Single European Sky policy, in terms of interoperability and seamless operations, although within the specific traffic pattern and structure of Mediterranean Area. In this respect, attentive and focused examination of the various applications developed in MEDUP may be needed to select those applications more apt to bring quick advantages in terms of benefit-to-cost. This examination is linked to the first line above as, possibly, different technologies may define preferred priority paths for applications or, even, feasibility in itself.

**A third line** may be oriented towards a comprehensive study and planning for the completion of Data Link Infrastructure over the Mediterranean Area, especially involving the States of the southern and eastern Mediterranean shores, as same States show strong increase of tourist traffic. Appropriate consideration should be given to the role of complementary surveillance enabled by ADS-B and to the possible substitution.
of SSR Radars to be decommissioned in the future.\(^5\)

The study should cover the expected advantages/benefits stemming from a large-scale implementation of ADS in the Mediterranean area, for which a preliminary hypothesis of Ground Station number and geographical siting will be appropriate but will need some assumption on actual feasible coverage and on appropriate overlap. A first guess has been presented in paragraph 5.2.2.5 above.

For this analysis, the use of CAPT (Coverage Analysis and Prediction Tool, now in development on behalf of Eurocontrol) and of other planning and simulation tools may be foreseen.

**A fourth line** should propose the exploitation of MEDUP results to areas (in Europe and outside Europe) different from Mediterranean but with similar air traffic problems.

**A fifth line** should comprise effective dissemination of actual results (including the different limitations experienced in MEDUP Programme), with the involvement of a large spectrum of stakeholders and with appropriate co-ordination with other parallel Programmes.

As a final conclusion, even if not all the different lines reported above may be actively pursued, the exploitation of MEDUP Work should be considered of relevant interest for the European Commission and for the Partners and should deserve further consideration in the next future.

\(^5\) *Note by HCAA*

The considerations for operational deployment of ADS-B by HCAA have been hindered so far by the lack of clarity as far as the technology question is concerned (long delays plaguing the so-called “global decision” on VDL-4/1090ES/UAT); now (July 2004), taking regard of (what looks like) the latest European “impetus” to explore the feasibility of Multi-Link Ground Stations and/or Transponders, HCAA will re-examine the issue.

One probable application concerns the possibility of ADS-B Ground Stations “at least” supplementing surveillance coverage in the areas currently covered by “aging” radars. In fact, at least five of the currently operating Greek radars will be over 15 years old by the years 2010-11, dates around which (from what it is predicted now) ADS-B is “expected” to be making “solid” steps with respect to “operational implementation”.

In addition, the discussion will certainly involve the possibility of gap-filling (through ADS-B) in the currently existing radar-coverage holes in the SW “corner” of the Greek FIR as well as in NE “corner” of the Greek FIR.
## 6. Acronym List

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>4-D</td>
<td>4 Dimensional</td>
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<tr>
<td>ADAP</td>
<td>Automatic Downlink of Aircraft Parameters</td>
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<td>ADS</td>
<td>Automatic Dependent Surveillance</td>
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<tr>
<td>ADS-B</td>
<td>Automatic Dependent Surveillance – Broadcast</td>
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<td>ADS MEDUP</td>
<td>ADS Mediterranean Upgrade.</td>
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<tr>
<td>AIDC</td>
<td>ATS Interfacility Data Communication</td>
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<tr>
<td>AMCP</td>
<td>Aeronautical Mobile Communications Panel</td>
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<tr>
<td>ASAS</td>
<td>Airborne Separation Assurance System</td>
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<tr>
<td>A-SMGCS</td>
<td>Advanced – Surface Movement Guidance and Control System</td>
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<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
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<tr>
<td>ATFM</td>
<td>Air Traffic Flow Management</td>
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<td>ATM</td>
<td>Air Traffic Management</td>
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<tr>
<td>ATN</td>
<td>Aeronautical Telecommunications Network</td>
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<td>ATS</td>
<td>Air Traffic Services</td>
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<td>ATSU</td>
<td>Air Traffic Services Unit</td>
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<td>AVT</td>
<td>ADS Validation Test-bed (AVT)</td>
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<td>CAA</td>
<td>Civil Aviation Authority</td>
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<tr>
<td>CBA</td>
<td>Cost and Benefits Analysis</td>
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<tr>
<td>CDTI</td>
<td>Cockpit Display of Traffic Information</td>
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<tr>
<td>CNS</td>
<td>Communication, Navigation and Surveillance</td>
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<tr>
<td>COTS</td>
<td>Commercial on The Shelf</td>
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<tr>
<td>CPDLC</td>
<td>Controller Pilot Data Link Communication</td>
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<tr>
<td>D-GNSS</td>
<td>Differential – Global Navigation Satellite System</td>
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<tr>
<td>DG</td>
<td>Directorate General</td>
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<tr>
<td>DG TREN</td>
<td>DG Trans European Network</td>
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<td>EC</td>
<td>European Commission</td>
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<td>ECAC</td>
<td>European Civil Aviation Conference</td>
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<td>EEC</td>
<td>Eurocontrol Experimental Centre</td>
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<td>EGNOS</td>
<td>European Global Navigation Optimisation System</td>
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<td>EUROCAE</td>
<td>European Organisation for Civil Aviation Equipment</td>
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<td>EU</td>
<td>European Union</td>
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<td>FAA</td>
<td>Federal Aviation Administration</td>
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<td>FANS</td>
<td>Future Air Navigation System</td>
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<tr>
<td>FARAWAY</td>
<td>Fusion of Radar and Automatic dependent surveillance data through 2 WAY data link</td>
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<tr>
<td>FDPS</td>
<td>Flight Data Processing System</td>
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<tr>
<td>FIS</td>
<td>Flight Information Service</td>
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<td>FIS-B</td>
<td>Flight Information Service – Broadcast</td>
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FMS  Flight Management System
GNSS  Global Navigation Satellite System
GPS  Global Positioning System
GRAS  Ground Regional-based Augmentation System
GTG  Gate To Gate
HMI  Human Machine Interface
ICAO  International Civil A Organisation
ICD  Interface Control Documents
JTB  Joint Technical Board
MAP  MEDUP Airborne Platform
MATS  Malta Air Traffic Services
MCAA  Malta CAA
MEDUP  see ADS MEDUP
MEDUP CDU  Airborne Display and Computing Unit
MGS  ADS-MEDUP Ground Station
MD  MacDonnell Douglas
MFF  Mediterranean Free Flight
MoC  Memorandum of Co-operation
NEAN  Northern European ADS-B Network
NUP  NEAN Update Programme
PC  Personal Computer
PMB  Programme Management Board
QPR  Quarterly Management Reports
SARPS  Standard and Recommended Practices
SATCOM  SATellite COMmunication
SBAS  Satellite Based Augmentation System
SCAA  Swedish Civil Aviation Authority
SC-TT  Saab Celsius Transponder Tech
SMAA  Study of Mediterranean and adjacent area for ADS
SMGCS  Surface Movement Guidance and Control System
STDMA  Self-organising Time Division Multiple Access
TBC  To be completed
TBD  To be defined
TCP  Trajectory Change Point
TIS  Traffic Information Service
TIS-B  Traffic Information Service – Broadcast
TMA  Terminal Manoeuving Area
ToR  Terms of Reference
TWR  ToWeR
VDL  VHF Digital Link
VHF  Very High Frequency
WP  Work Package
WBS  Work Breakdown Structure
7. Annexes

Note: the Annexes have a three figure numbering: the first figure reminds that the Annex belongs to Section 7, the second figure indicates the Section of the Final Report to which they refer, the third figure is a progressive numbering

ANNEX 7.5.1

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Appendix

Attachment A

STATEMENT OF ICAO POLICY ON CNS/ATM SYSTEMS
IMPLEMENTATION AND OPERATION

Approved by the ICAO Council on 9 March 1994 and amended on 28 June 1996

In continuing to fulfil its mandate under Article 44 of the Convention on International Civil Aviation by, inter alia, developing the principles and techniques of international air navigation and fostering the planning and development of international air transport so as to ensure the safe and orderly growth of international civil aviation throughout the world, the International Civil Aviation Organization (ICAO), recognizing the limitations of the present terrestrial-based system, developed the ICAO communications, navigation and surveillance/air traffic management (CNS/ATM) systems concept, utilizing satellite technology.

ICAO considers an early introduction of the new systems to be in the interest of healthy growth of international civil aviation.

The implementation and operation of the new CNS/ATM systems shall adhere to the following precepts:

1. UNIVERSAL ACCESSIBILITY

The principle of universal accessibility without discrimination shall govern the provision of all air navigation services provided by way of the CNS/ATM systems.

2. SOVEREIGNTY, AUTHORITY AND RESPONSIBILITY OF CONTRACTING STATES

Implementation and operation of CNS/ATM systems which States have undertaken to provide in accordance with Article 28 of the Convention shall neither infringe nor impose restrictions upon States’ sovereignty, authority or responsibility in the control of air navigation and the promulgation and enforcement of safety regulations. States’ authority shall be preserved in the co-ordination and control of communications and in the augmentation, as necessary, of satellite navigation services.

3. RESPONSIBILITY AND ROLE OF ICAO

In accordance with Article 37 of the Convention, ICAO shall continue to discharge the responsibility for the
adoption and amendment of Standards, Recommended Practices and Procedures governing the CNS/ATM systems. In order to secure the highest practicable degree of uniformity in all matters concerned with the safety, regularity and efficiency of air navigation, ICAO shall co-ordinate and monitor the implementation of the CNS/ATM systems on a global basis, in accordance with ICAO’s regional air navigation plans and global co-ordinated CNS/ATM systems plan. In addition, ICAO shall facilitate the provision of assistance to States with regard to the technical, financial, managerial, legal and co-operative aspects of implementation. ICAO’s role in the co-ordination and use of frequency spectrum in respect of communications and navigation in support of international civil aviation shall continue to be recognized.

4. TECHNICAL CO-OPERATION

In the interest of globally co-ordinated, harmonious implementation and early realization of benefits to States, users and providers, ICAO recognizes the need for technical co-operation in the implementation and efficient operation of CNS/ATM systems. Towards this end, ICAO shall play its central role in co-ordinating technical co-operation arrangements for CNS/ATM systems implementation. ICAO also invites States in a position to do so to provide assistance with respect to technical, financial, managerial, legal and co-operative aspects of implementation.

5. INSTITUTIONAL ARRANGEMENTS AND IMPLEMENTATION

The CNS/ATM systems shall, as far as practicable, make optimum use of existing organizational structure, modified if necessary, and shall be operated in accordance with existing institutional arrangements and legal regulations. In the implementation of CNS/ATM systems, advantage shall be taken, where appropriate, of rationalization, integration and harmonization of systems. Implementation should be sufficiently flexible to accommodate existing and future services in an evolutionary manner. It is recognized that a globally co-ordinated implementation, with full involvement of States, users and service providers through, inter alia, regional air navigation planning and implementation groups, is the key to the realization of full benefits from the CNS/ATM systems. The associated institutional arrangements shall not inhibit competition among service providers complying with relevant ICAO Standards, Recommended Practices and Procedures.

6. GLOBAL NAVIGATION SATELLITE SYSTEM

The global navigation satellite system (GNSS) should be implemented as an evolutionary progression from existing global navigation satellite systems, including the United States’ global positioning system (GPS) and the Russian Federation’s global orbiting navigation satellite system (GLONASS), towards an integrated GNSS over which Contracting States exercise a sufficient level of control on aspects related to its use by civil aviation. ICAO shall continue to explore, in consultation with Contracting States, airspace users and service providers, the feasibility of achieving a civil, internationally controlled GNSS.

7. AIRSPACE ORGANIZATION AND UTILIZATION

The airspace shall be organized so as to provide for efficiency of service. CNS/ATM systems shall be implemented so as to overcome the limitations of the current systems and to cater for evolving global air traffic demand and user requirements for efficiency and economy while maintaining or improving the existing levels of safety. While no changes to the current flight information region organization are required for implementation of the CNS/ATM systems, States may achieve further efficiency and economy through consolidation of facilities and services.

8. CONTINUITY AND QUALITY OF SERVICE

Continuous availability of service from the CNS/ATM systems, including effective arrangements to minimize the operational impact of unavoidable system malfunctions or failure and achieve expeditious service recovery, shall be assured. Quality of system service shall comply with ICAO Standards of system integrity and be accorded the required priority, security and protection from interference.
9. COST RECOVERY

In order to achieve a reasonable cost allocation between all users, any recovery of costs incurred in the provision of CNS/ATM services shall be in accordance with Article 15 of the Convention and shall be based on the principles set forth in the *Statements by the Council to Contracting States on Charges for Airports and Air Navigation Services* (Doc 9082), including the principle that it shall neither inhibit nor discourage the use of the satellite-based safety services. Cooperation amongst States in their cost-recovery efforts is strongly recommended.
ANNEX 7.5.2

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Appendix
Attachment D

A32-19: Charter on the Rights and Obligations of States Relating to GNSS Services
(approved in October 1998)

Whereas Article 44 of the Convention on International Civil Aviation, signed on 7 December 1944 (the “Chicago Convention”), mandates the International Civil Aviation Organization (ICAO) to develop the principles and techniques of international air navigation and to foster the planning and development of international air transport;

Whereas the concept of the ICAO communications, navigation and surveillance/air traffic management (CNS/ATM) systems utilizing satellite-based technology was endorsed by States and international organizations at the ICAO Tenth Air Navigation Conference, and was approved by the 29th Session of the Assembly as the ICAO CNS/ATM systems;

Whereas the Global Navigation Satellite System (GNSS), as an important element of the CNS/ATM systems, is intended to provide worldwide coverage and is to be used for aircraft navigation;

Whereas GNSS shall be compatible with international law, including the Chicago Convention, its Annexes and the relevant rules applicable to outer space activities;

Whereas it is appropriate, taking into account current State practice, to establish and affirm the fundamental legal principles governing GNSS; and

Whereas the integrity of any legal framework for the implementation and operation of GNSS requires observance of fundamental principles, which should be established in a Charter;

The Assembly:

Solemnly declares that the following principles of this Charter on the Rights and Obligations of States Relating to GNSS Services shall apply in the implementation and operation of GNSS:

1. States recognize that in the provision and use of GNSS services, the safety of international civil aviation shall be the paramount principle.

2. Every State and aircraft of all States shall have access, on a non-discriminatory basis under uniform conditions, to the use of GNSS services, including regional augmentation systems for aeronautical use within the area of coverage of such systems.

3. a) Every State preserves its authority and responsibility to control operations of aircraft and to enforce safety and other regulations within its sovereign airspace.
b) The implementation and operation of GNSS shall neither infringe nor impose restrictions upon States' sovereignty, authority or responsibility in the control of air navigation and the promulgation and enforcement of safety regulations. States' authority shall also be preserved in the co-ordination and control of communications and in the augmentation, as necessary, of satellite-based air navigation services.

4. Every State providing GNSS services, including signals, or under whose jurisdiction such services are provided, shall ensure the continuity, availability, integrity, accuracy and reliability of such services, including effective arrangements to minimize the operational impact of system malfunctions or failure, and to achieve expeditious service recovery. Such State shall ensure that the services are in accordance with ICAO Standards. States shall provide in due time aeronautical information on any modification of the GNSS services that may affect the provision of the services.

5. States shall co-operate to secure the highest practicable degree of uniformity in the provision and operation of GNSS services.

States shall ensure that regional or subregional arrangements are compatible with the principles and rules set out in this Charter and with the global planning and implementation process for GNSS.

6. States recognize that any charges for GNSS services shall be made in accordance with Article 15 of the Chicago Convention.

7. With a view to facilitating global planning and implementation of GNSS, States shall be guided by the principle of co-operation and mutual assistance whether on a bilateral or multilateral basis.

8. Every State shall conduct its GNSS activities with due regard for the interests of other States.

9. Nothing in this Charter shall prevent two or more States from jointly providing GNSS services.
ANNEX 7.5.3

ANC 11/WP009

Agenda Item 1: Introduction and assessment of a global air traffic management (ATM) operational concept

“INTEROPERABILITY” AND “SEAMLESS” CONSIDERATIONS IN AIR TRAFFIC MANAGEMENT

(Presented by the Secretariat)

SUMMARY

The terms “interoperability” and “seamless” are often used when describing the future air traffic management (ATM) system; however, a common understanding of these notions is not always obvious. This paper presents the work of the Air Traffic Management Operational Concept Panel (ATMCP) on establishing a common understanding of the notions of “interoperability” and “seamless” and includes a high-level framework for their use within the context of the ATM operational concept and of a global ATM system.

Action by the Conference is in paragraph 3.

1. INTRODUCTION

The terms “interoperable”, “interoperability”, “seamless” and “seamlessness” are often used when referring to the future air traffic management (ATM) system and, in particular, when attempting to convey the expectations of that system. The Air Traffic Management Operational Concept Panel (ATMCP) therefore found it necessary to come to a common understanding of these terms in order to progress its work and to fully describe the future ATM system.

In attempting to arrive at a common understanding of the notions of “interoperability” and “seamless”, the ATMCP reviewed the work of other bodies in this respect and found that, in most cases, such work was based on a more technical framework and was referenced to technical systems. It was therefore necessary to develop these notions within the context of an ATM system, which includes operators, pilots, air traffic controllers, procedures, as well as systems and other agents.

A number of relevant factors were identified that served to characterize the notions of “interoperability” and “seamless” and that need to be addressed when considering these terms. Among these factors are issues of:

a) scalability;

b) human and non-human agents;

c) whether interoperability should have defined qualifiers;

d) relationship to expectations of uniformity;

e) what constitutes a “seam” or discontinuity;

f) visibility of transitions, as some visibility may be useful;

g) whether imbedded standards are implied or required;

h) the wide range of meanings of these terms in current use;
i) discontinuities occurring over an extended time period;

j) whether seamless implied interoperability, and whether the definition of seamless should refer to interoperability;

k) domain of common standards; and

l) the importance of perspective in relation to seamless.

Based on the above, and in order to help with the understanding of the ATM operational concept, the following explanations of the notions of interoperability and seamless were developed by the ATMCP to serve as working terms for use toward development of the ATM operational concept.

**Interoperability** within the ATM system may be described as the ability to transfer information or effect functionality across any discontinuity, in order to enable operations.

**Seamless** within the ATM system may be described as the property that allows a transition across any discontinuity which, from the perspective of the transiting agent, does not require a considered action to facilitate the transition. It should be noted that, in this context, seamless does not imply ATM systems convergence into singleness.

From the above, it can be seen that interoperability is primarily associated with the need for systems, people and procedures, among other things, to operate effectively across disparate systems.

Seamless is primarily associated with the needs of the user or operators of a system. An important objective of a seamless ATM system is to ensure that as aircraft operate across different regions where various levels of service exist, those services would be delivered in a manner that allows the aircraft to operate seamlessly, with a consistent level of safety being provided.

The global ATM system should be interoperable in all cases, and seamless wherever and whenever possible.

### 2. EFFECT ON ATM REQUIREMENTS

The importance of having a more precise understanding of the terms “interoperability” and “seamless” is reinforced by the growth and evolution of systems that lack global uniformity in technical definition.

It is apparent that systems existing within a highly prescriptive and technically standardized environment have a commonality of definition, design, function, and application which makes the notions of “interoperability” and “seamless” superfluous in the manner described above. In such cases, there is no need to prescribe interoperability or seamlessness requirements as all systems and models would be produced by a few manufacturers to the highly prescriptive technical standards mentioned above (e.g. airborne collision avoidance system (ACAS)).

While this may be beneficial in some ways for a limited number of systems, it would have an overall negative effect on the global aviation system if it were applied across all systems. The temptation to excessively apply prescriptively-defined standards at a global level for all levels of ATM requirements in order to achieve a transparency of functions, procedures and operations must, therefore, be avoided.

There is a balance needed that would accommodate existing systems while ensuring that emerging systems and new technological solutions can be integrated in the air navigation infrastructure.

In achieving balance, it is important to consider the need for consistency in ATM functionality both for system development and user interface. This can be achieved respectively by defining interoperability requirements and designs that provide for seamlessness.
Under cover of AN-Conf/11-WP/21, the meeting will discuss the need for ICAO to develop ATM requirements based on the ATM operational concept. When determining ATM requirements, it will be essential that minimum corresponding requirements for interoperability and seamlessness are defined. This would provide the appropriate “top-down” specification for a globally interoperable ATM system.

To achieve the desired balance between specificity and flexibility, the ATM requirements must not be over-specified.

The figure in the Appendix provides some examples of the relationship between a common domain of standards and interoperability. It shows how interoperability can be achieved across differing domains of standards.

3. ACTION BY THE CONFERENCE

The Conference is invited to agree on the following recommendation:

That ICAO, when developing ATM requirements, define corresponding minimum requirements for interoperability and seamlessness.
Appendix
ANNEX 7.5.4

A35-WP/145

Agenda Item 14: Aviation security

ATM RELATED SECURITY INITIATIVES IN EUROPE
(Presented by 41 Contracting States, Members of the European Civil Aviation Conference)


* Member States of the European Union are indicated with an asterisk in the above list.

SUMMARY

This paper describes progress regarding ATM security related activities based on the strategic security initiatives previously presented to ICAO.

It identifies issues, for review by ICAO, concerning unlawful interference, alert classification, intercept procedures, communications failure, communications watch and training.

The paper has been elaborated and coordinated by EUROCONTROL.

ACTION BY THE ASSEMBLY

Action by the Assembly is in paragraph 5.

1. INTRODUCTION

Aviation security within Europe is a political priority. ICAO has undertaken valuable work to safeguard against the unlawful interference with aircraft. A complementary activity, focusing on measures to deal with an unlawful interference, has been jointly promoted by EUROCONTROL and the North Atlantic Treaty Organisation (NATO). This activity supports the four security strategic initiatives that were presented to the ICAO High-level, Ministerial Conference on Aviation Security held in February 2002, namely:

a) Establish processes to optimise the sharing of Civil Air Traffic Control (ATC) and Military (ATC/Air Defence) radar information;

b) Create a European Regional Focal Point for Air Traffic Management information, involving civil and military interests;

c) Give priority to the validation of a high capacity air-ground communications capability for the transmission of encrypted cockpit voice, flight data and on-board video information;

d) Ensure that both civil and military ATC procedures and training, relating to hijack and other emergency situations, are reviewed and harmonised.

Close co-ordination with ECAC on security related issues has been maintained through the ECAC Security Working Group.
Close co-operation with NATO has been achieved through the NATO EUROCONTROL ATM Security Coordination Group (NEASCOG). NEASCOG is studying possible improvements for ATM security, at minimum cost to airspace users.

2. BACKGROUND ON STRATEGIC SECURITY INITIATIVE ACTIVITIES

NEASCOG in close co-operation with the ECAC Security Working Group and other International and National organisations is proposing a feasibility study into a low-cost, cross-border network called ERRIDS (European Regional Renegade Information Dissemination System) for consideration by States. Its purpose is to share information, on a need-to-know basis, with organizations having counter-terrorism responsibilities. These include state organisations, civil ATM service providers, the military, police agencies, air carriers and airports. The secure exchange of information would be based on NATO accredited security software.

The first ERRIDS application to be tested addresses the failure of aircraft communication. There are several reasons for communication failure ranging from equipment problems to the selection of the wrong radio frequency. Whatever the reason, it will likely result in military interception. In certain parts of Europe interceptions are often required, and the associated cost to States of launching fighter aircraft is high. ERRIDS will be able to help by, for example, automatically notifying the flight operations centre of the airline. The centre would be able to attempt to contact the aircraft, using data link or the radio channel reserved for airline operations communications (AOC), and instruct it to contact air traffic control (ATC) immediately. The aircraft itself could have a high capacity secure link into ERRIDS. This would allow the exchange of encrypted information.

To avoid the need for modified Secondary Surveillance Radar (SSR) transponders, at airspace user cost, NEASCOG has worked to exploit the potential of using military primary radar information. A successful test conducted by EUROCONTROL and NATO has demonstrated that, on loss of the civil SSR information, military primary radar track information can, under certain circumstances, automatically made available to the civil radar processing system.

3. INTERCEPTION OF CIVIL AIRCRAFT

Unlawful interference

Guidance is provided by ICAO on the interception of civil aircraft by state aircraft regarding visual signals and other means of communication between the aircraft, specific manoeuvres and the actions by the civil aircraft to be taken for immediate landing. Detailed intervention procedures for this situation are established at national level.

A decision by the designated national authority to intercept a civil aircraft will be based on the first indication of a “suspected unlawful interference” since a prompt reaction might be required. Therefore, it is extremely important that the authority responsible for the interception has a complete understanding of the type of situation on-board the aircraft.

There is a need for air traffic controllers and flight crew to be fully aware of security-related procedures through appropriate training.

Types and phases of unlawful interference

The 11th Air Navigation Conference Recommendation 2/9 states: “That, consistent with the ICAO Aviation Security Plan of Action and the ATM operational concept, ICAO consider developing in-flight emergency response and coordination procedures for air traffic controllers, together with training guidance, related to
the distinctly different types and phases of unlawful interference. These procedures and guidance material should allow for the different conditions which exist in States”.

To avoid any misunderstandings and confusion, it is essential that the levels of threat are defined. ICAO has defined the following four levels:

- Level 1 – Disruptive behaviour
- Level 2 – Physical abusive behaviour
- Level 3 – Life threatening behaviour
- Level 4 – Attempted breach or actual breach of the flight crew compartment

New emerging threats have appeared since these levels were established. Accordingly, the changed security environment requires some augmentation of these levels to be reported by flight crew.

*Interception procedures*

Interception procedures were first developed for use during times of military tension and war. Later the same procedures were also used for interceptions of aircraft being subjected to unlawful interference. However, where aircraft might be used as a weapon, a different military intervention would be required.

In some States and regions, interceptions are carried out frequently. Recent experiences show that there is a need to review the current interception procedures and signals. Subjects to be taken into consideration include:

- the effect on TCAS of the interception;
- signals related to the threat level onboard;
- signals/manoeuvres when control has been seized by terrorists;
- possible military intervention;
- weather conditions;
- assignment of emergency airfields at national level;
- increased awareness of civil pilots of interception procedures; and
- quick reference guide of procedures and signals in the cockpit.

### 4. COMMUNICATIONS

In certain regions civil aircraft are unnecessarily intercepted because they are suspected of being subject to unlawful interference. This is frequently due to failure of communication between ATC and the pilot. Causes for such failure of communication include equipment malfunction, incorrect selection of frequency, and inattention by the pilot. Aircraft interceptions pose, by their very nature, a certain risk. Consequently, there is a need to minimize unnecessary interceptions to avoid potentially hazardous situations.

Under certain circumstances, the VHF emergency frequency (121.5 MHz) should be monitored, both by aircraft and appropriate ATC providers. However, it is recognised that normal airline practice is to use one radio for ATC and the second for AOC.
It is therefore proposed that the requirement for continuous watch of the emergency frequency should be reviewed taking into account, as appropriate, the current use of AOC voice communication, data link and other communications systems.

5. ACTION BY THE ASSEMBLY

The Assembly is invited to recommend that ICAO, when conducting reviews of security provisions, take into account the following ATM related issues:

a) the improvement of the ICAO interception procedures and signals;

b) the specification of global standardization of the threat levels relating to unlawful interference and their reporting by flight crew;

c) the improvement of the ICAO communication failure procedures and the monitoring, when appropriate, of the VHF emergency frequency (121.5 MHz); and

d) the continuing need for security related training for air traffic controllers and flight crew.
Executive Summary

At its previous meetings the ACG has first selected financial incentives and then route charge modulation with full cost recovery as the most attractive and practical way to encourage airlines equipage with novel ATM features.

This paper illustrates how route charge modulation can indeed be used as a practical, implementable and effective tool to achieve this objective.

Recommendation

The Members of the ACG are invited

- to comment on the principles and approach of the concrete example described in this paper;
- to note that the Agency, based on the received comments, will prepare a paper on route charge incentives applied to the LINK 2000+ Programme for submission to the Director General for further consultation with the Member States.
1. INTRODUCTION

1.1. At its 16th meeting, the ACG expressed a preference for financial incentives as a means to encourage airborne equipage with novel ATM features. This preference was later confirmed by the CESC. At its 18th meeting, the ACG selected route charge reduction with immediate cost recovery as the most realistic option out of a list of mechanisms proposed by the Agency Task Force.

1.2. This paper looks in more detail at route charge reduction with immediate cost recovery applied to the introduction of data link; it highlights the issues that need to be addressed and it provides an example using actual CRCO flight data and route charge rates.

2. THE PURPOSE OF INCENTIVES

2.1. The purpose of incentives is to accelerate the equipage of aircraft with suitable avionics to support an ATM improvement, in those cases where the benefits of such an equipage is not immediate and is not solely for the aircraft that are equipped.

2.2. The introduction of some technologies to improve the efficiency of the ATM system requires capital investment from airspace users (avionics on board aircraft). If a mandate for equipage is not necessary, is not the optimal way to introduce the new technology or is considered inappropriate in view of the economic situation, a steady increase in the rate of equipage may be difficult to achieve. This problem will occur specifically with capital investments of which some of the expected benefits, e.g. reduced delays and ANS provision costs, are collective and late.

2.3. In this case financial incentives for airspace users to equip early with new technology on board aircraft are a means to achieving an optimal equipage rate and thus optimising benefits of the investments made on the ground and on board aircraft.

2.4. The results of the accelerated equipage are greater ATM cost savings, improved flight efficiency and reductions in delays.

3. THE PREFERRED OPTION: ROUTE CHARGE REDUCTION WITH IMMEDIATE COST RECOVERY

It is useful to summarise the characteristics of the ACG preferred option:

- Equipped aircraft are given a route charge reduction.
- The income loss incurred by this reduction is recovered through a slight route charge increase for the non-equipped aircraft.
- Consequently, the ANS costs are fully recovered - as they are today.

4. AN EXAMPLE: THE INTRODUCTION OF DATA LINK (THE LINK 2000+ PROGRAMME)

4.1. General considerations

4.1.1. Data link is a good example of a new ATM feature that requires the support of incentives to ensure a smooth introduction.

4.1.2. A "big bang" introduction with a mandate, like the one necessary for RVSM or 8.33 kHz, is not required for data link. Aircraft may be equipped gradually and this can even be considered as desirable:

- it allows controllers to get acquainted with data link with a few aircraft first, and gradually to be exposed to more data link aircraft;
- pilots will be confronted with a small number of data link services, provided by a limited number of centres first, gradually extending to more services available in a wider area.
4.1.3. A mandate is consequently not required from the outset. Moreover, it would be unreasonable to impose a mandate in the short term, in view of the current economic situation of the airline industry.

4.1.4. Conversely, we must ensure that the number of aircraft gradually increases to allow the avionics industry to make the right investment decisions with a reasonable risk. To do this, measures should be taken to encourage equipage.

4.2. An example

4.2.1. In order to facilitate the discussion around this subject, the LINK 2000+ Programme has worked out an example of a possible implementation with the help of the Central Route Charges Office. This example allows everybody to see the nature and size of the incentive for the equipped aircraft and the size of the implication for the non-equipped aircraft.

The simulation was done with the following working assumptions:

- The airspace in which route charge reductions are offered is the airspace where the Air Navigation Service providers are committed to the LINK 2000+ Programme and are, or will be, providing a data link service within the time frame of the programme (before 2008). This airspace consists of the airspace of Belgium, France, Germany, Italy, Luxembourg, the Netherlands, Portugal and Spain, above FL 245.
- The route charge reduction amounts to 2% on the charge applicable in the concerned airspace (i.e. that part of the flight conducted in the upper airspace).
- The loss incurred by this reduction is compensated by an increase of the charge of the non-equipped aircraft in the same airspace.

The traffic sample used was that of 6 June 2002.

4.2.3. Two scenarios were tested:
- a "2005 scenario" where it is expected that 100 aircraft will be equipped
- a "2007 scenario" where it is expected that 25% of the B737s, A320s and MD80s will be equipped.

In both scenarios the aircraft were assumed to perform 4 flights a day, which is less than average for most airlines.

4.3. The results

The results can be summarised as follows:

4.3.1 2005 scenario

The average saving for an equipped flight would be 13 € per flight. This amounts to 52 € (4 flights) per day or 17680 € (340 days) per year.
To recover this reduction, non-equipped flights will have to pay 0.47 € more per flight, 1.88 € per day, and 639.2 € per year.

Conclusion: The advantage for equipped flights is considerable and will certainly accelerate equipage. The penalty for non-equipped flights is very small.

4.3.2 2007 scenario

The average saving for an equipped flight would be 13 € per flight. This amounts to 52 € (4 flights) per day or 17680 € (340 days) per year.
To recover this reduction, non-equipped flights will have to pay 1.63 € more per flight or 6.52 € per day, 2216.8 € per year.

**Conclusion:** In this scenario the advantage for the equipped aircraft is the same but the penalty for the non-equipped is higher. This indicates that it may be necessary to review the incentive for equipped flights periodically in function of the number of equipped aircraft, in order to modulate the reduction to avoid an unreasonable penalty for non-equipped fights. Obviously, these reviews must be planned and published in advance, to allow airlines to base their investment decisions on stable data.

4.3.3 An airline example

If we take the example of Spanair, a medium-size carrier (45 aircraft, 3000 employees, with a 50% charter, 50% scheduled operation) the results are as follows:

If Spanair would equip 5 aircraft, which conduct a total of 22 flights per day, these aircraft would save in the "2007 scenario", € 643.47 per day or **€ 218,778.98** per year. The other 40 aircraft, unequipped, would have to pay a total surcharge of € 168.87 per day or **€ 57,415.61** per year. So the overall benefit for Spanair would still be € 161,363.37 per year.

**Conclusion:** This example shows that even with a small equipage effort, the airline can reap the benefits of this effort.

5. CONCLUSION

The example worked out in paragraph 4.2 demonstrates that a small route reduction for equipped aircraft can be a convincing argument to encourage equipage.

The route charge reduction is easy to apply and calculate, it is predictable and it is cost saving for equipped aircraft, thus rewarding the concerned airline for an investment that profits all airspace users.

Route charge modulation is a powerful tool to minimise the investment risk of airlines and in doing so to change their behaviour towards avionics investment.

6. RECOMMENDATION

The Members of the ACG are invited

- to comment on the principles and approach of the concrete example described in this paper;
- to note that the Agency, based on the received comments, will prepare a paper on route charge incentives applied to the LINK 2000+ Programme for submission to the Director General for further consultation with the Member States.
ANNEX 7.5.6

A35-WP/10

REPORT BY THE COUNCIL ON REGULATION AND ORGANIZATION OF AIRPORTS AND AIR NAVIGATION SERVICES

SUMMARY
This paper reports on developments in regulation and organization of airports and air navigation services since 2001 and envisions the need for further guidance on commercialization and privatization in this field as well as guidance on international cooperation regarding implementation of a global air navigation system.

REFERENCES
Doc 9082/6, ICAO’s Policies on Charges for Airports and Air Navigation Services
Doc 9562, Airport Economics Manual
Doc 9161, Manual on Air Navigation Services Economics
Circ 284, Privatization in the Provision of Airports and Air Navigation Services

Quoting from the Report

3. IMPLEMENTATION OF A GLOBAL AIR NAVIGATION SYSTEM

General
The implementation of a global air navigation system will require an extended and large-scale international cooperation at all levels to secure an efficient, gradual and region-by-region transition process.

A comprehensive ICAO policy and guidance material on organizational and economic aspects of the provision and operation of air navigation services already exists, including guidance on international cooperation between States at a sub-regional as well as at a regional level in the form of international operating agencies, joint charges collection agencies, multinational facilities and services and joint financing arrangements.

General guidelines on the establishment and provision of multinational air navigation facilities and services are now contained in all regional air navigation plans. Based on the establishment of an international treaty or an administrative agreement, all these forms of international cooperation could technically be applied to include a whole region.

In the short and medium term, ICAO’s role in fostering the development of international cooperation will focus on the practical guidance and assistance to States (and regions). As mentioned above (paragraph 2.3), the commercialization process of air navigation services is still in its development phase and the guidance material on key aspects of commercialization will therefore need to be expanded. This material is essential also for the understanding and active participation of all parties concerned (national regulators/providers, regional regulators/providers and all airspace users) in the
planning, implementation and operation of the future global air navigation system.

**Collection problems**

Following a recommendation by the 33rd Session of the Assembly the issue of the recovery of unpaid air navigation services charges was added to the terms of reference of the Air Navigation Services Economics Panel (ANSEP). The Panel has accordingly developed a proposal on new policy guidance and expanded guidance material on collection problems. The proposal emphasizes the need for an established collection policy and outlines the essential functions of a successful collection machinery. In this context, in paragraph 18 of Doc 9082/6, the Council recommends that States or their delegated service providers consider participating in joint charges collections agencies whenever this is advantageous.

**GNSS cost allocation**

The issue concerning the allocation of GNSS costs among the various user groups has been included in the work programme of the organization during the last few years. ANSEP, which has been assigned the task to assist the Secretariat in undertaking the study, has agreed that the cost allocation of GNSS between civil aviation and other users should take place at the regional level and that it should be based on the requirements of different user categories. Coordination with other organizations and non-aeronautical users will be necessary to obtain support for proposals in the ICAO study.