Volume 1. Executive Summary
**Document control**

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**Document purpose and scope**

This document is Volume 1 of the Final Summary and Conclusion Report submitted after completion of the North European CNS/ATM Application Project (NEAP). It summarises the objectives, assumptions, methodology, testing, results, and conclusions of the Project.

The Final Summary and Conclusion Report is divided into three Volumes:

1. Executive Summary (this volume),
2. Final Consolidated Progress Report with an Appendix and several Annexes,

Each of these Volumes is a separate and standalone document with its own intended audience.

Together with the Executive Summary in Volume 1, Volume 2 comprises the full report, including all contracted documentation for all applications evaluated in the Project, and is primarily intended for the European Commission, the Project’s Steering Committee and the participating organisations. Volume 3 provides a fairly detailed overview of the Project and its conclusions and recommendations, and is intended to enable the results to be brought to a wider audience within the aviation industry.

Volume 1, this Executive Summary, is intended as a very broad summary of the Project and could be used as a first introduction to more detailed studies of the other volumes or as an overview of the project for understanding the significance of its results.
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# Abbreviations and acronyms

This list comprises only those abbreviations and acronyms used in the Executive Summary. A complete list is provided in Volumes 2 and 3.

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<th>Abbreviation</th>
<th>Description</th>
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<td>ADS</td>
<td>Automatic Dependent Surveillance</td>
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<tr>
<td>ADS-B</td>
<td>ADS-Broadcast</td>
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<tr>
<td>AFTN</td>
<td>Aeronautical Fixed Telecommunications Network</td>
</tr>
<tr>
<td>AGH</td>
<td>Ängelholm airport</td>
</tr>
<tr>
<td>ARN</td>
<td>Stockholm-Arlanda Airport</td>
</tr>
<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
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<tr>
<td>ATM</td>
<td>Air Traffic Management</td>
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<tr>
<td>ATIS</td>
<td>Automatic Terminal Information Service</td>
</tr>
<tr>
<td>ATIS-B</td>
<td>ATIS-Broadcast</td>
</tr>
<tr>
<td>CAT</td>
<td>[approach] Category (I, II,III)</td>
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<tr>
<td>CCC</td>
<td>Cellular CNS Concept</td>
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<tr>
<td>CDTI</td>
<td>Cockpit Display of Traffic Information</td>
</tr>
<tr>
<td>CFIT</td>
<td>Controlled Flight Into Terrain</td>
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<tr>
<td>CNS</td>
<td>Communications, Navigation, Surveillance</td>
</tr>
<tr>
<td>CPDLC</td>
<td>Controller-Pilot Data Link Communications</td>
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<tr>
<td>CWP</td>
<td>Controller Working Position</td>
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<tr>
<td>DCAA</td>
<td>Danish Civil Aviation Administration (SLV)</td>
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<tr>
<td>DFS</td>
<td>Deutsche Flugsicherung GmbH</td>
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<tr>
<td>DGNSS</td>
<td>Differential GNSS</td>
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<tr>
<td>DLH</td>
<td>Deutsche Lufthansa</td>
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<tr>
<td>DLR</td>
<td>Deutsche Zentrum für Luft und Raumfahrt</td>
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<tr>
<td>EHS</td>
<td>Extended Helicopter Surveillance</td>
</tr>
<tr>
<td>EUROCAE</td>
<td>EUROPean Organisation for Civil Aviation Equipment</td>
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<tr>
<td>ETSI</td>
<td>European Telecommunications Standardisation Institute</td>
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<tr>
<td>FIS</td>
<td>Flight Information Services</td>
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<td>FIS-B</td>
<td>FIS-Broadcast</td>
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<tr>
<td>FMS</td>
<td>Flight Management System</td>
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<tr>
<td>FREER</td>
<td>FREE Route experiment</td>
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<tr>
<td>GNSS</td>
<td>Global Navigation Satellite System</td>
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<td>GRAS</td>
<td>GNSS Regional Augmentation System</td>
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<tr>
<td>HMI</td>
<td>Human-Machine Interface</td>
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<td>ICAO</td>
<td>International Civil Aviation Organization</td>
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<td>IPV</td>
<td>Instrument Approach with Vertical Guidance</td>
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<td>JAA</td>
<td>Joint Aviation Authorities</td>
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<td>JTSO</td>
<td>Joint Technical Standards Order</td>
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<tr>
<td>LFV</td>
<td>Luftfartsverket (SCAA)</td>
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<td>NEAN</td>
<td>North European ADS-Broadcast Network</td>
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<td>NUP</td>
<td>NEAN Update Programme</td>
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<tr>
<td>NM</td>
<td>Nautical Mile</td>
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<td>NPA</td>
<td>Non-Precision Approach</td>
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<tr>
<td>NUP</td>
<td>NEAN Update Programme</td>
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<tr>
<td>PETAL</td>
<td>Preliminary Eurocontrol test of Air/ground data Link</td>
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<td>RIMS</td>
<td>Runway Incursion Monitoring System</td>
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<td>Required Navigation Performance</td>
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<td>Search and Rescue</td>
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<td>SAS</td>
<td>Scandinavian Airlines</td>
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<td>Swedish Civil Aviation Administration (LFV)</td>
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<td>SCAT-I</td>
<td>Special Category I</td>
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<td>SLV</td>
<td>Statens Luftfartsvæsen (DCAA)</td>
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<tr>
<td>SMR</td>
<td>Surface Movement Radar</td>
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<tr>
<td>STDMA</td>
<td>Self-organising Time Division Multiple Access</td>
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<tr>
<td>TDI</td>
<td>Track Deviation Indicator</td>
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<td>TIS</td>
<td>Traffic Information Services</td>
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<tr>
<td>TIS-B</td>
<td>TIS-Broadcast</td>
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<td>TWR</td>
<td>Control Tower</td>
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<tr>
<td>VDL</td>
<td>VHF Digital Link</td>
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<tr>
<td>VHF</td>
<td>Very High Frequency</td>
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<tr>
<td>WIAS</td>
<td>Weather Information Automated Systems</td>
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1 Overview of the project

1.1 Sponsorship and partners
The North European CNS/ATM Applications Project (NEAP) was sponsored by the Directorate General VII of the European Commission within Transport Research Programme of the 4th Framework Programme.

The following organisations participated in the project:
- Deutsche Lufthansa (DLH)
- Scandinavian Airlines (SAS)
- Deutsche Flugsicherung GmbH (DFS)
- Statens Luftfartsvæsen; the Danish Civil Aviation Administration (DCAA)
- Luftfartsverket; the Swedish Civil Aviation (SCAA).

Each of the project partners was responsible for activities within a specific segment of the project, but activities were closely co-ordinated across segment boundaries. Testing activities took place in Germany, Denmark and Sweden.

The SCAA was the project co-ordinator.

1.2 Objectives
The overall project objectives of NEAP were to investigate, specify, develop, test and evaluate civil aviation user applications and services within an integrated communications (broadcast), navigation and surveillance (CNS) concept. Activities focused on the following domains:
- Enhanced surveillance for Air Traffic Control (ATC)
- Pilot situation awareness
- GNSS (Global Navigation Satellite System) precision navigation capability for all phases of flight.

Each of these domains includes one or more applications that cover aspects of different phases of flight in a gate-to-gate concept.

1.3 Project life cycle
NEAP started on 1 September 1997 and ended on 31 December 1998.

1.4 Technology background
The International Civil Aviation Organization (ICAO) has adopted the CNS/ATM concept. This concept envisages the use of data link communications, satellite navigation systems and automatic dependent surveillance (ADS) in the future provision of air traffic management (ATM). When implemented, this new global system will provide the aviation community with a replacement of current systems and technology.

A number of projects are ongoing worldwide to determine how to implement the mix of satellite, air and ground technologies in the most optimal way. To achieve the greatest benefits from the introduction of the new technology all airspace users must be appropriately equipped. The required equipment has to be affordable and suitable for all user groups. This implies that future systems will have to be based on multi-purpose, low cost equipment. The applications using this equipment must be user friendly.

The Self-organising Time Division Multiple Access (STDMA) technology is currently being developed to meet the requirements for modern data link to support a range of CNS domains.
Several national and international projects have focused on the demonstration of the basic technology and its application in support of ground and airborne users, and work on international standardisation is ongoing. ICAO has adopted VDL (VHF Digital Link) Mode 4 as the designation for the STDMA technology when standardised for civil aviation.

STDMA was the enabling technology in NEAP, providing the necessary platform for the testing and evaluation. Operating in the VHF band, STDMA/VDL Mode 4 is capable of handling time-critical information in well-defined time slots for air-to-air, air-to-ground and ground-to-ground data communications. Messages can be broadcast to all users or addressed to specific users (end-to-end). The primary application of the technology is ADS-Broadcast (ADS-B), which provides not only controllers, but pilots too, with a highly accurate display of nearby traffic. The North European ADS Broadcast Network (NEAN) project, another project sponsored by the European Commission and a sister project of NEAP, provided the ground and air infrastructure to allow the extensive testing of specific broadcast CNS/ATM applications conducted within NEAP to take place. The NEAN ground infrastructure consists of a number of ground stations that provide consistent VHF coverage across a large part of northern Europe. A ground station exchanges data through the STDMA/VDL Mode 4 data link with “transponder” equipment on-board aircraft and ground vehicles, and with other ground stations through the ground network. The Cellular CNS Concept applied in NEAN replicates the handling of communications in the ground infrastructure of a mobile telephone system.

A significant number of airborne and ground users have been equipped to date with an STDMA/VDL Mode 4 transponder allowing broadcast of position reports to the ground and to other airborne users as well as reception of position reports, GNSS augmentation and other data.

Figure 1. NEAN coverage at 30,000 ft

User display equipment were key to the testing conducted in NEAP. Six DLH B747s, two SAS F28s and two DC9s, one MAERSK HELICOPTERS’ Super Puma, one DLR Do-228 and several ground vehicles formed the backbone of mobile platforms used in the testing.

1.5 The gate-to-gate concept

Today, a range of dissimilar and segregated communication, navigation and surveillance systems supports pilots and controllers in different phases of flight and airspace types. The emergence of data link services creates an opportunity to establish integrated, “seamless” gate-to-gate services to pilots and ATC alike. In NEAP, several examples of data link applications and services, based on a single technical platform, were tested and evaluated.

1.6 NEAP applications

The data link applications tested and evaluated in NEAP are essential in
meeting the requirements of the future CNS/ATM system. The following applications were included in the test program (the responsible organisation is given within brackets):

- GNSS precision navigation capability for en-route and approach (SAS)
- On ground situation awareness/ taxi guidance (DLH)
- In-flight situation awareness (DLH)
- Enhanced ATC surveillance – downlink of aircraft parameters (DFS)
- Automatic Terminal Information Service broadcast; ATIS-B (DFS)
- Extended helicopter surveillance (DCAA)
- Runway incursion (SCAA).

Hence at least one application, or service, of each component of the CNS/ATM concept was included in NEAP. Combined, they provided a basis for evaluating a single system solution for seamless gate-to-gate operations, i.e. a system that supports pilot and controllers in all phases of flight from the departure gate, through pushback, taxing, take-off, climb, en-route, descent, approach, landing and taxiing to docking at the arrival gate.

Following is a brief, generic, description of the fundamental techniques on which these applications and services are based. A more detailed description of each particular application/service is given later in the document.

1.6.1 Automatic Dependent Surveillance – Broadcast

Automatic Dependent Surveillance – Broadcast (ADS-B) is a new aviation surveillance concept whereby aircraft transmit their positions (usually derived from a GNSS receiver on-board the aircraft) over a radio data link. In a fully implemented system, position information is transmitted and received by every aircraft in the vicinity so that all users have knowledge of their own location and the locations of all other aircraft. The position information may be displayed in the cockpit of suitably equipped aircraft to give new situation awareness capabilities. Also, ground vehicles and fixed ground stations can be equipped to transmit and receive position data, providing surveillance of all types of traffic and a two-way data link capability.

ADS-B is an enabling technique that can help deliver the free flight concept to airspace users.

STDMA/VDL Mode 4 supports ADS-B for all phases of flight. When supporting ground operations, it allows taxiing aircraft and airport vehicles to be monitored from the control tower. This could provide a safety net against unintentional runway incursion.

1.6.2 Pilot situation awareness

Data link communications will remove the “party line”, i.e. the possibility for pilots to monitor the voice communications between ATC and other aircraft. Pilots will therefore lose their present situation awareness. ADS-B, with an appropriate cockpit display (commonly known as a Cockpit Display of Traffic Information (CDTI)), gives a much better situation awareness to help overcome this concern. In the future, ADS-B and a CDTI will provide the pilot with full situation awareness of all surrounding traffic, including intent as appropriate, and will also show own aircraft position superimposed on a moving map in all phases of flight. As ADS-B also works on ground, a CDTI may be used to support taxiing and detect other aircraft and airport vehicles in low visibility conditions.

1.6.3 Enhanced ATC surveillance

ADS-B data transmitted will provide accurate and reliable surveillance information for ground ATC. This information can be used to enhance the
quality of surveillance. For example, position data can be supplemented with aircraft parameter data from the FMS or airborne computers. Such data can also be used by the airline technical support.

1.6.4 GNSS augmentation

When using GNSS data for navigation or surveillance, a GNSS augmentation system can be used to improve the quality of the position data. GNSS augmentation signals transmitted by data link from satellites or ground stations provide information on the quality of the GNSS signals and correction data to overcome intentional and unintentional errors in the signals from the satellites. There are several possible approaches to augmentation and one is the GNSS Regional Augmentation System (GRAS). With GRAS, a network of STDMA/VDL Mode 4 ground stations gathers data on GNSS satellite integrity and calculates augmentation information. The augmentation information is transmitted from the ground to the aircraft, possibly using the same data link as that used to support ADS-B and other applications.

Using the STDMA/VDL Mode 4 data link to augment satellite navigation signals can give very high accuracy of position information, for example, 1-2 m in the horizontal plane. This allows aircraft and ground vehicles to navigate in the air and on the ground using the augmented position information. The service provided by GRAS will be appropriate for most navigation applications including approach operations down to Instrument Approach with Vertical Guidance (IPV).

1.6.5 Communications

A data link can be used to transmit data in a point-to-point or broadcast fashion. Point-to-point, or addressed, transmissions, as investigated in the PETAL II project, can be used for controller-pilot data link communications (CPDLC) for exchange of mainly routine messages.

Broadcast transmissions from the ground to many aircraft simultaneously can be used to provide broadcast uplink of, for instance, meteorological data, flight information services (FIS) and traffic information services (TIS).

TIS-B provides broadcast uplink of radar derived position data, and is suitable as a complement to ADS-B during transition when all aircraft have not yet been equipped. TIS-B is considered as an surveillance function. Automatic Terminal Information Service-Broadcast (ATIS-B) is used to transmit airport information and weather data to aircraft for display on the CDTI.

1.7 Relationship with other projects

- **NEAN.** As noted above, NEAN provided the ground and airborne infrastructure necessary for the testing and evaluation carried out in NEAP.

- **PETAL II.** Managed by Eurocontrol Brussels, PETAL II focuses on the use of data links for real-time CPDLC, that is, point-to-point communications between ATC and aircraft. One of the data links used by PETAL II is STDMA/VDL Mode 4, and the project is using some of the aircraft also used by NEAP for its trials.

- **FREER III.** The FREER projects aim to lay the foundation for a future “free flight” concept in which more autonomy and authority in the ATM system are placed on the aircraft. In FREER III, experiments are carried out on the use of an air-to-air data link to detect and resolve conflicts. Experiments include the use of the STDMA/VDL Mode 4 data link technology and CDTI as a means for displaying ADS-B derived traffic and traffic...
advisories.

- FARAWAY, DEFAMME, FAA SAFEFLIGHT 2000 and Magnet B are other projects using the same technology or sharing project objectives.

## 2 Project Objectives

The NEAP project objectives must be viewed on two levels. Overall project objectives relate to the suitability of an integrated CNS system supporting a range of operational services and multiple phases of flight. Specific objectives relate to the potential benefits to be gained by the individual applications and their use in a future CNS/ATM concept. The specific objectives also relate to the capability and suitability of the STDMA/VDL mode4 system to support these applications and services.

### 2.1 Overall objectives

As noted in the project overview above, the overall project objectives of NEAP were to investigate, specify, develop, test and evaluate civil aviation user applications and services within an integrated CNS concept. Emphasis was to be placed on gaining “real-world” experience.

Testing and evaluation activities would focus on the following domains of applications and services:

- Enhanced surveillance for ATC
- Pilot situation awareness
- GNSS precision navigation capability for all phases of flight.

Each of these domains includes one or more applications that cover aspects of all phases of flight in a gate-to-gate concept. Therefore, the testing and evaluation activities included the verification of the suitability of a single technical system solution to support ATC and aircrew from pushback to docking at the arrival gate.

### 2.2 Specific objectives

Throughout the testing and evaluation conducted within each application, feedback from aircrews and ATC was to be gathered for analysis. Such data would be useful for improvement of equipment and services and refinement of HMI. Experience from the testing would be used for further concept development and safety analyses.

The following specific objectives relating to one or more applications were adopted:

- Gathering of operational feedback on the CDTI HMI, which include digital maps of European airspace and airports.
- Gathering technical and operational feedback on broadcast of flight information services.
- Gathering of technical and operational feedback on a combined ADS-B and DGNSS concept for approach and landing.
- Gathering of technical and operational feedback on surveillance in previously unserved airspace, such as surveillance of low-altitude operations in the North Sea.
- Preliminary analysis of safety implications of combining different CNS applications in a single technical system.
- Development of preliminary operational requirements for a CNS system supporting gate-to-gate operations.
Refinement of the Cellular CNS Concept (CCC).

In addition, application-specific objectives were defined.

Application orientation in NEAP means that emphasis was on operational suitability rather than technical performance. However, applications and technical performance are closely linked – poor system technical performance inevitably leads to poor operational performance and therefore low rating by operators. International standardisation organisations also place formal technical requirements on applications, such as update rate, accuracy and reliability.

The testing and evaluation of applications in NEAP therefore in effect also applied to the capability of the technical system to support those applications. Therefore, testing and evaluation of the system characteristics and performance formed an important part of NEAP activities.

3 Methodology

This section outlines the test methodology applied in NEAP.

The objective of NEAP was to evaluate the operational benefits of services associated with different applications of data link techniques. In addition, the ability of the data link technology (STDMA/VDL Mode 4) employed to support those applications and services was to be evaluated.

The evaluation of the suitability of a certain service must be based on judgements and opinions expressed by experienced users, i.e. pilots and controllers, who were to base their judgements on a comparison between their experience from the current (non-data link) service and the service being tested in NEAP. Moreover, certain functional requirements, such as Required Navigation Performance (RNP) parameters for en-route navigation and approach, must be met by the technical systems, and data to support technical evaluation must be collected and analysed.

Each of the services tested in NEAP, as well as the scenario in which the testing was to be conducted, was clearly specified in a Service description, a Realisation plan and a Test plan for each service to be tested. However, since testing of certain services took place in a live operational environment onboard commercial aircraft and helicopters and at ATC units, the scenarios could not always be fully controlled. The expected benefits were stated in the service description, and used as assumptions that were to be accepted or rejected through the testing activities.

Questionnaires were used to gather opinions and comments from the users and the answers were analysed statistically. In addition to gathering “subjective” data through questionnaires, data from various technical sources, such as the NEAN network, onboard MMI and ATC systems was collected and used in the evaluation of the technical systems. Emphasis in testing and evaluation was placed on common “key” factors such as safety, impact on workload, technical limitations and required improvements.

Evaluations made for individual services were used to arrive at conclusions regarding the overall capability and suitability of a system solution to
support CNS/ATM applications and services in all phases of flight, i.e. “a part of a seamless gate-to-gate CNS/ATM system”.

## 4 Applications

The project designation NEAP implies an applications oriented project. The achievement of the overall and specific requirements assumed the availability of a properly functioning ground and airborne infrastructure and basic services offered by that infrastructure.

The basic ground and airborne infrastructure was provided by NEAN, which provided the following data and services within its coverage area:

- ADS-B information,
- differential GPS data (DGPS),
- rudimentary end-to-end message delivery (not used in NEAP),
- CDTI functionality onboard participating aircraft,
- network management and maintenance functions,
- data broadcast capability.

In addition to dependency on the NEAN technical platform, NEAP included development of NEAP-specific equipment and functionality. For instance, the testing of GNSS approach required the development of a new ground station at Ängelholm, an upgrade of the CDTI developed within NEAN, and integration of additional flight instruments.

### 4.1 Precision Navigation

*This application was demonstrated in cooperation between SAS and the SCAA.*

#### 4.1.2 Operational context

Modern aircraft are capable of navigating without overflying fixed navigation aids on the ground. Area navigation can be supported, for instance, by use of satellite navigation. Basic GNSS accuracy and integrity can be augmented by differential GNSS (DGNSS) signals. The presence of DGNSS is needed for more demanding approach and landing operations.

Non-Precision Approach (NPA) is a major contributor to Controlled Flight Into Terrain (CFIT) accidents. Lack of vertical guidance and poor situation awareness is a main reason.

#### 4.1.3 NEAP application

The precision navigation service tested in NEAP was supported by the STDMA/VDL Mode 4 data link. Differential corrections were broadcast from ground stations and ADS-B reports were received from equipped aircraft and ground vehicles. En-route navigation and approach testing was conducted using two SAS Fokker 28s on scheduled service between Stockholm-Arlanda (ARN) and Ängelholm (AGH). The approach into AGH was made as an Instrument Approach with Vertical guidance (IPV). Two separate Track Deviation Instruments (TDI) were installed to provide lateral and vertical guidance to the pilots during
final approach. The TDI was used together with the CDTI, which provided situation overview throughout en-route navigation and approach phases of flight.

A new ground station was developed and installed at AGH. It used a combination of a commercial SCAT-I system for generating differential corrections and an STDMA/VDL Mode 4 system for providing the two-way data link capability to support DGNSS broadcast and reception of ADS-B reports. New display equipment was installed in the AGH control tower (TWR). The availability of NEAN data allowed the controller to view, in a seamless fashion, aircraft positions from the departure gate at ARN through the en-route, approach, landing and taxiing phases into the parking position at AGH.

4.1.4 Testing and evaluation

Testing included the collection and evaluation of both operational and technical data. The main testing platform was the two specially equipped SAS Fokker F28s, but testing also focused on the AGH ground station and equipment in the TWR. System characteristics were tested to assess the system’s performance and potential to support seamless CNS/ATM gate-to-gate operations. The operational aspects and benefits were assessed through questionnaires and interviews.

4.1.4 Results and conclusions

The following bullet points summarise principal findings.

- All application-specific objectives were met, and the assumptions on expected benefits and system characteristics were accepted.
- The evaluated service provided operational benefits in terms of improved situation awareness for pilots and controllers.
- The system delivers support for approach and landing and can be assumed to provide support for seamless gate-to-gate operations.
- The combination of ADS-B and GNSS augmentation using a single data link provides a solution for all phases of flight.
- The workload on the pilots with a future system is expected to be equal or reduced compared to ILS.
- Collaborative procedures could be developed between pilots and controllers to enhance capacity in the terminal area.
- A number of ATC benefits enabled by ADS-B were identified.

4.2 On-ground situation awareness and taxi guidance

This application was demonstrated by DLH.

4.2.1 Operational context

One of the bottlenecks in today's growing air traffic is the ground traffic at busy airports. The efficiency of aircraft movements on ground, although skilfully managed by ground controllers, still very much depends on weather conditions and is far away from being optimised.

Previous trials have demonstrated that ADS-B based on STDMA/VDL Mode 4 works equally well on the ground as in the air. Own position and the positions of other aircraft can be shown on a cockpit display, superimposed on a moving map of the airport. As ADS-B reports include the identity of the transmitting aircraft or vehicles, this information is included in the informa-
tion presented. This leads to a much-improved pilot awareness of nearby traffic in poor visibility.

By combining a cockpit display with a suitable HMI, it is possible to create a taxi guidance system that leads to more efficient, safer and weather-independent ground movements.

4.2.2 NEAP application

The on-ground situation awareness and taxi guidance service evaluated in NEAP is based on ADS-B reports transmitted and received by six DLH Boeing 747-200 aircraft, other STDMA/VDL Mode 4 equipped aircraft and airport vehicles at the Frankfurt International Airport. The ADS-B reports were based on very accurate DGNSS position data. High-precision airport maps were used in the B747 cockpit displays.

The test program included revenue ground operations of the DLH B747s at Frankfurt during the test period.

4.2.3 Testing and evaluation

Testing included collection and evaluation of operational data using questionnaires. A set of hypotheses was established before testing as the basis for the questionnaires.

4.2.4 Results and conclusions

The tests lead to different results depending on the degree of development and deployment in the field.

• Small benefits were achieved already with the trial equipment.

• Visual reference is required for collision avoidance during ground operations, requiring restrictions to be applied in low visibility conditions. Therefore a suitable taxi guidance display is required in order to make use of the ADS-B features on ground.

• Taxi guidance increases safety and may reduce taxi time on unfamiliar airports.

• Taxi guidance down to CAT III conditions is possible, allowing a significantly higher flow of ground traffic under low visibility conditions, provided that a suitable taxi guidance display is available and operational procedures are in place.

• On-ground situation awareness allows aircraft to maintain separation independent of weather.

This leads to the following recommendations for future work:

• Research in regards to human factors, including selection and layout of traffic information to avoid information overload in the cockpit,

• Partnership with airframe manufacturers and integration of VHF based ADS-B equipment in a modern transport aircraft,

• Development of operational procedures to make use of achievable benefits.

Finally, procedures should be developed and implemented to enable benefits to be gained during a transition phase when not all aircraft have been equipped with an STDMA/VDL Mode 4 based ADS-B system.
4.3 In-flight situation awareness

This application was demonstrated by DLH.

4.3.1 Operational context

Today, most major international airports face severe problems in accommodating the increasing air traffic, especially at peak hours. The problems are even more severe in poor weather conditions. The identification of new methods to maximise the flow of outbound and inbound traffic is therefore a major challenge.

To allow a weather independent constant flow of traffic, application of visual procedures in instrument weather conditions should be a possible option, provided that suitable means for providing pilots with information on surrounding traffic are in place. This would put the pilot in the ATC information loop and enables him to take an active role in the air traffic management process.

If relevant surveillance information is presented in the cockpit, new operational procedures could be implemented that would allow, under certain circumstances, the delegation of separation responsibility from ATC to the cockpit. One possible “visual” procedure would be “station keeping”, where the aircrew maintains own separation to a preceding aircraft.

4.3.2 NEAP application

The in-flight situation awareness service tested in NEAP was based on ADS-B position reports and radar data uplinked from the ground being received by an STDMA/VDL Mode 4 transponder in six DLH Boeing 747-200 aircraft. This information was presented on a dedicated display in the cockpit, the MMI 5000. The display provided precise area and airport maps on which the positions of ADS-B equipped aircraft and uplinked radar data were superimposed.

Traffic representation on the cockpit display included a label showing the aircraft’s identity (usually the flight number), relative altitude and a prediction vector.
4.3.3 Testing and evaluation

Testing included collection and evaluation of operational data using questionnaires. All tests were based on the NEAP test methodology. Hypotheses were established before testing as a basis for the development of the questionnaires. A clear distinction was made between existing trial equipment and an assumed certified system, and between single flight experience and extended experience from the service being evaluated.

4.3.4 Results and conclusions

The trials with the ADS-B system in regards to in-flight situation awareness lead to different results depending on the degree of development and deployment in the field.

- TIS-B (uplink of radar data) enables in-flight situation awareness in high traffic density airspace with few ADS-B equipped aircraft.
- ADS-B based in-flight situation awareness forms the basis for an additional safety net with pre-warning times much longer than for TCAS, and therefore allows for early tactical flight path coordination rather than last minute conflict avoidance, resulting in increased safety margin and redundancy.
- In-flight situation awareness including the display of the flight number of other aircraft allows aircrews to optimize their flight profile according to the traffic situation (e.g. change of flight levels between company aircraft).
- Weather independent constant throughput and increased capacity is possible through adaptation of VMC procedures to IMC (e.g. follow visually, climb through level of selected aircraft).
- Airborne station keeping with increased capacity is possible provided that separation responsibility is clearly defined and operational procedures are in place.
- In-flight situation awareness closes the information loop between ATC and the aircraft allowing delegation of responsibilities to the cockpit. As a result, ADS-B based free flight scenarios in low density airspace are possible in the long term.
- Potential to apply reduced separation minima due to enhanced surveillance accuracy.

Finally, uplink of radar data via TIS-B is a key factor in transition phase.

4.4 Enhanced surveillance for ATC

This application was demonstrated by DFS

4.4.1 Operational context

Today’s ATC surveillance is primarily based on radar data. With secondary radar (SSR), identity and altitude is added to the basic position data, and the tracking function in modern ATC systems automatically calculates the speed, vertical attitude and track. The controller’s forward planning is based on current radar data combined with information in the flight plan. Information on a flight’s actual intentions must be communicated by means of voice.

Increasing load on voice channels and capacity problems in high-density areas require that the controller be provided with improved planning data. The onboard flight management system (FMS) knows exactly the flight path of the entire flight. Access to such precise FMS data for ATC could increase efficiency, reduce delays and costs for airlines and provide an additional safety net.
4.4.2 **NEAP application**

The application evaluated in NEAP was based on enhanced surveillance (ENH) data, broadcast by an appropriately equipped experimental aircraft and received by the NEAN ground network. Data was presented on a controller working position. The specification of DAP (Download of Aircraft Parameter) was used to select the information flags. The experimental aircraft supported the following ARINC 429 labels (information):

- Aircraft address
- SSR Mode 3A
- Magnetic Heading
- Roll angle (bank)
- Flight Level (barometric)
- Rate of Turn
- Ground Speed
- Wind Speed/Wind Direction

The DAP data delivered by the ARINC 429 bus system was accepted and converted into the STDMA/VDL Mode 4 format and subsequently broadcast every second on the data link. Each report contained the aircraft data listed above.

4.4.3 **Testing and evaluation**

The flight test was performed by the DLR experimental aircraft DO-228. The aircraft was equipped with an ARINC 429 interface card and an STDMA GNSS transponder.

The conversion of the aircraft data was performed by a software application.

4.4.4 **Results and conclusions**

The results provided a perception of how ground system functions such as radar tracking could be improved by using downlinked aircraft parameters. Aircraft intentions and manoeuvres could be detected faster using common radar systems.

The following points summarise the principal results and conclusions:

- The evaluated STDMA/VDL Mode 4 system was capable of demonstrating the downlink of aircraft parameters.
- The format used for the downlink has to be improved and adjusted to operational requirements

The DFS Project JANE (Joint Air Navigation Experiments) has determined that with improved strategic and tactical planning the potential number of conflicts (delays, sector load etc.) may be reduced significantly. The on-board FMS is one of the major elements in the information chain. Only the FMS knows at take-off time the exact four dimensional flight profile, better than a ground system could ever compute it. There is a unified synchronised time required for all users and systems. The STDMA/VDL Mode 4 system uses the GPS UTC time and could provide this time to other systems.

The picture above shows typical changes of wind direction and the increasing velocity during the climb phase based on DAP broadcast data. Future work will include comparison with wake vortex data.
4.5 Automatic Terminal Information Service – Broadcast

This application was demonstrated by DFS.

4.5.1 Operational context

One of the standard operating procedures in today’s operational environment is for pilots to obtain weather and airport information from the Terminal Information Service prior to departure and arrival. The Air Traffic Service Providers are providing the information on the Automatic Terminal Information Service (ATIS) frequency as voice information. The pilot selects the appropriate ATIS frequency and listens to the information. For a written copy of the ATIS information the pilot has to write down the information manually.

The ATIS-B service evaluated in NEAP provided a data link broadcast service to deliver the ATIS information into the cockpit. The pilot used the ATIS function on the cockpit display to access the information.

4.5.2 NEAP application

The ATIS-B service was based on the data link functionality of the NEAN STDMA system. The ATIS information received from the German weather information systems (WIAS) was automatically broadcast by all German NEAN ground stations. Appropriately equipped aircraft within the coverage of a German ground station would receive ATIS messages from all participating airports. The pilot had the possibility to display the current, as well as previously received ATIS messages from different German airports using the MMI 5000 cockpit display system.

4.5.3 Testing and evaluation

The system tests were divided into a system characteristics test and an operational benefits test.

The system characteristics test was based on monitoring of the message flow through the system. Different steps were defined to;

- verify the applicability of the ATIS conversion module,
- demonstrate the ATIS reception at a selected flight, and
- evaluate an ATIS coverage map.

The operational benefits test was based on questionnaires developed in co-operation with DLH. A statistical evaluation of the questions concerning the ATIS service was done.

4.5.4 Results and conclusions

A significant percentage of the ATIS messages were not delivered to airborne users. The main bottleneck related to the conversion process, 9% of all ATIS messages obtained from the AFTN could not be used for the ATIS data link service because of an error message from the conversion module. The major problems were;

- the use of a free text AFTN ATIS format, and
- the use of a not exactly defined phraseology in the AFTN ATIS format.

The ATIS coverage had nearly the same characteristics and range as the ADS-B coverage. From a technical perspective, if applying the results from the Frankfurt ground station to all NEAN ground stations, aircraft within the overall NEAN coverage volume would be able to utilize the ATIS-B service.

To improve the ATIS presentation on the cockpit display pilots strongly requested a cockpit printer and the use of standard abbreviations rather than plain text.
4.6 Extended Helicopter Surveillance

This application was demonstrated by SLV.

4.6.1 Operational Context

For helicopter operations in an uncontrolled airspace without radar coverage, situation awareness for the Air Traffic Control (ATC) relies entirely upon flight plans and position reports from the pilots using voice radio communication during the flight.

Continuously updated visual information on aircraft position will improve situation awareness and reduce the tension for ATC should a position over-voice arrive later than expected. Reliable and accurate information regarding the last known position would improve the probability for a successful Search and Rescue (SAR) operation, especially when weather conditions are rough and visibility low.

4.6.2 NEAP application

The purpose of the Extended Helicopter Surveillance (EHS) service was to extend situation awareness for air traffic controllers providing radar supported flight information service by supplying enhanced visual capabilities for a designated area of the North Sea, which is only partly covered by radar. The EHS service was extended with a CDTI in a helicopter and an ADS-B-only display system on ground to obtain feedback from pilots and the helicopter operator.

The EHS service was based on ADS-B position reports broadcast by an STDMA/VDL Mode 4 equipped helicopter and received by ground stations. Ground stations were installed in Esbjerg and Børsnæs - both located at the West Coast of Jutland - and on the Tyra East platform, located in the North Sea, approximately 125 nautical miles from the coast and outside radar coverage. The ADS-B position reports were distributed through the NEAN ground infrastructure and displayed together with conventional radar data - when within radar coverage - on a dedicated Controller Working Position (CWP). The CWP is situated in the Copenhagen ATC centre close to the controllers providing flight information and alerting services for the area.

4.6.3 Testing and Evaluation

No special test flights were conducted for the evaluation. All tests relied on data from regular commercial flights between Esbjerg and offshore installations in the North Sea with a Super Puma from MAERSK HELICOPTERS.

The service evaluation included collection of both operational and technical data. Detailed technical data from all NEAN sensors used by the service was collected and analysed and questionnaires were developed for collecting operational feedback from controllers who provide flight information service and helicopter pilots.

4.6.4 Results and Conclusions

The Extended Helicopter Surveillance service showed the following benefits:

- Enabled ATC to monitor a helicopter traffic down to 1000 feet from Esbjerg Airport to offshore installations in the North Sea, beyond radar coverage.
- According to the helicopter operator, the system provides correct position to the ADS-B-only Display Station almost continuously, despite several problems encountered in the current test implementation.
- The test results indicate that a future extended surveillance solution for the examined area can be established using the STDMA/VDL Mode 4 technology.
4.7 Runway incursion monitoring

This application was demonstrated by the SCAA.

4.7.1 Operational context

Unauthorised or unintentional entry onto runways and taxiways by aircraft and vehicles constitutes a serious threat to aviation safety. Hazardous conflict situations may develop between aircraft and airport ground vehicles in, for instance, snow clearing situations when several vehicles operate on, or close to an active runway. The threat is more critical when poor visibility conditions prevent the controllers in the control tower (TWR) to visually monitor ground movements and aircraft on final approach.

4.7.2 NEAP application

The runway incursion monitoring service tested in NEAP was based on ADS-B reports from appropriately equipped aircraft and airport vehicles being presented on a dedicated display in the TWR. The Runway Incursion Monitoring System (RIMS), developed for the NEAP test programme, included functions that enabled TWR controllers and vehicle drivers to be automatically alerted when a hazardous situation developed.

The test scenarios were designed to replicate potential airport conflict situations such as:

- vehicle too close to active runway as aircraft is landing,
- aircraft still on runway as next aircraft is landing.

Alert conditions that applied to these and similar situations were developed. Alert conditions included warning when a conflict risk was present, and alarm when there was an actual conflict. Alerts generated visual and audible indications.

4.1.5 Testing and evaluation

Testing included collection and evaluation of both operational and technical data. Scenario testing involved the TWR, specially equipped airport vehicles and a BE200 flight inspection aircraft. Other STDMA/VDL Mode 4 equipped aircraft and vehicles served as “background traffic” that only played a passive role in the tests. Most scenarios were designed to replicate conflicts between aircraft and ground vehicles and between two aircraft, both airborne and on ground. One set of scenarios was specifically designed to serve as the basis for assessment by controllers and addressed many different conflict situations. Such assessment was made through questionnaires, which addressed operational aspects of individual RIMS functions and the usefulness of the system. The completed questionnaires were used to draw conclusions regarding operational benefits.

4.7.4 Results and conclusions

The following bullet points summarise the principal results and conclusions.

- The evaluated system provided significant operational benefits in terms of safety, reduced controller workload, improved situation awareness, and improved capacity in low visibility conditions.
- The evaluated system was technically viable. However, it was not possible, during the course of the trials, to implement algorithms that covered all possible conflict situations.
- It is possible to realise, through relatively limited technical and economic means, a powerful RIMS
based on ADS-B and the STDMA/VDL Mode 4 technical platform.

5 Certification road map

5.1 Certification Activities
The following NEAP Applications are addressed below:

- Station keeping using Airborne Situation Awareness – CDTI.
- ATIS Broadcast at European Airports.
- RNP approach using a combined ADS-B/DGNSS ground-station.

The Certification process has been analysed from a European perspective, assuming that these applications will be certified in Europe before the US. The study outlines:

- the content of a certification application,
- potential certification owners,
- identification of required certification bodies,
- possible road map for certification of applications,
- potential problems,
- required time for certification,
- EC activities to support European certification of applications.

A legal survey was carried out of European legislation to support the certification activities.

5.2 NEAP Certification Analysis
NEAP illustrates several fundamental problems currently preventing EU airlines and airports capitalising on the potential benefits of CNS/ATM technologies. These problems and their effects are common to European CNS/ATM initiatives and include the;

- fragmented European regulatory framework,
- lack of enforcement and confusion over the status of EU legislation,
- critical dependence of European Regulation on the FAA and on US Industry bodies,
- dominant US influence at ICAO,
- dominant position of US manufacturing interests.

Individual NEAP Application projects show that modern technical solutions exist for European and world-wide capacity and safety issues. These solutions are constrained by the lack of a coherent European regulatory framework that is needed to bring them to the market. Individual European regulatory authorities are reluctant to issue approvals on their own initiative unless based on a ‘transatlantic dialogue’ i.e. the support of the US regulatory infrastructure (including FAA, RTCA, AEEC etc.) Limited progress is only made after the most intense and careful negotiation between a major airline and its regulatory authority – often initially resulting in “Company only procedures”. This limits the availability of these solutions to the market and greatly reduces the rate of introduction.

5.3 Recommendations
The following key recommendations are made:

- Development of European Standards - to support VDL Mode 4 and its exploitation.
- These European Standards (ENs) should include:
- radio performance (for TA),
- data link performance,
- communication services and applications,
- network standards and performance requirements.
- Incorporate European standards for VDL Mode 4 into JAA JTSOs for certification/installation in aircraft.

• Development of JAA Operational Standards for ADS-B airborne applications.
• Rationalisation of regulatory framework and enforcement of legislation.
• Development of a certification strategy for VDL Mode 4

6 Conclusions and recommendations

6.1 General
The overall project objectives of NEAP were to investigate, specify, develop, test and evaluate civil aviation user applications and services in the Communications(broadcast), Navigation and Surveillance (CNS) domains. The set of applications and services developed in the project was designed to involve different phases of flight in order to assess whether a common technical platform could be used to support ATC and aircrew in gate-to-gate operations across CNS domains.

The technical platform used for all applications and services evaluated in NEAP was the STDMA/VDL Mode 4 data link. Whilst the main focus in NEAP was on applications and services, testing and evaluation of the technical characteristics of the data link in support of these operations were also key objectives.

It should be noted that the results and conclusions are based on the assumption that operational systems and applications will be fully integrated in the cockpit and ATC working positions.

6.2 Results and conclusions
As for the project objectives, the results and conclusions from NEAP should be viewed on two levels:

• The results and conclusions from the individual applications. These also included evaluation of new operational methods. These results and conclusions are stated in the application descriptions earlier in this document. Further information can be found in Volume two of the NEAP Final Summary and Conclusions Report.

• The results and conclusions on a “system” level based on the results and conclusions from the applications level. These overall results and conclusions relate to the capability of a technical platform, i.e. the STDMA/VDL Mode 4 technology, to support applications and services through out all phases of flight (“gate-to-gate”) and across CNS domains(excluding point-to-point communications). They also relate to conclusions drawn with regard to operations in a wider context.

1 Point-to-Point communications were intentionally not evaluated in NEAP. See Eurocontrol PETAL II documentation for further information.
The following bullet points summarise the main findings on the system level. They are based on results from all applications evaluated within NEAP.

**Operational:**
- Surveillance, both for ATC and cockpit, provided by ADS-B is feasible in all phases of flight, including surface operations. It works equally well on different types of aircraft, helicopters and ground vehicles.
- ADS-B can support several applications currently being developed, e.g. Airborne Situation Awareness – AIRSAW and Advanced Surface Movement Guidance and Control – A-SMGCS.
- Operational use of ADS-B in airborne and ATC installations requires careful analysis of Human Machine Interface (HMI) issues.
- Capacity and safety can be improved in unserved airspace by using ADS-B.
- Uplink of radar based information i.e. TIS-B is needed when introducing ADS-B applications in the cockpit.
- The operational concept of ADS-B is not complete and needs to be developed further taking into account the actual and expected European ATM requirements in terms of capacity and safety.
- Operational implementation of STDMA/VDL Mode 4 requires close co-ordination between ground service providers (CAAs), airlines, airports and industry.
- The aviation community currently lacks sufficient information on emerging CNS/ATM concepts like ADS-B.

**Technical**
- The combination of CNS broadcast services using a common technical platform is feasible.

STDMA/VDL Mode 4 provides a suitable system solution.
- Organised broadcast services of DGNSS, TIS-B and FIS-B (e.g. ATIS) is feasible and potentially very spectrum efficient. Coverage is the same as for ADS-B.
- STDMA/VDL Mode 4 is a feasible system solution for a ground-based regional augmentation system (GRAS). The combination of a SCAT-1 ground station with an STDMA/VDL Mode 4 data link is potentially a viable technical solution for GRAS.
- STDMA/VDL Mode 4 message throughput is not fully satisfactory under all conditions and needs further investigation and validation.

For additional supporting technical data see NEAN Final report.

### 6.3 Recommendations

- Introduction of ADS-B in Europe should be encouraged, especially in unserved airspace where near term benefits can be expected.
- Further development of ADS-B and associated applications requires close co-operation with airframe and ATC airport system manufacturers. Discussions to that end should be initiated.
- Study the integration aspects of ADS-B and DGNSS augmentation based on the GRAS concept evaluated in NEAP.
- Develop operational procedures related to the use of ADS-B in Europe.
- Initiate research on human factors regarding cockpit layout of traffic information (CDTI).
- Initiate extensive cost/benefit analyses with respect to ADS-B and other broadcast applications.
- Analyse certification issues for ADS-B and other broadcast serv-
ices. Promote the development of European Standards (e.g. ETSI), JAA Joint Technical Standards Orders (JTSOs) and JAA Operational Standards.

- Analyse safety, certification and operational approval aspects of using a common data link standard and a mix of different applications.

### 6.4 Lessons learned

The NEAP project was conducted in a short time frame (15 months). Another aspects was the fairly broad scope of work including both technical and operational development. The results were achieved with a tremendous effort by the partners. Based on experiences from the project work a number of lessons learned can be mentioned:

- Proof of concept trials, like NEAP, can be set-up and completed on a short time scale.
- A clear operational concept is required as a basis for the operational and technical assessment.
- Time and effort must be spent on defining the applications and services as well as the potential benefits.
- Liaison with other activities in the field e.g. industry, Eurocontrol, EC-projects, US activities is important to avoid duplication of work.
- Avoid mixing of technical and operational evaluation methods.
- Differentiate between prototype systems and operational systems and the impact on the evaluation.
- It is important to have the support from both airlines, airports and ATC when conducting CNS/ATM projects.
- Support and commitment from manufacturer of air (avionics and airframer) and ground equipment is essential.

### 7 Future work

The results from NEAP will be used in the EC sponsored (TEN-T) NEAN Update Programme (NUP). NUP will also take into account work performed in other European projects like; NEAN, FARAWAY, DEFAMM, SUPRA, PETAL II and FREER III.

NUP will focus on moving from R&D to preparation for operational implementation through, *inter alia*, extensive upgrade of the network architecture, capabilities and management functions and incorporation of VDL Mode 4 compliant equipment. A GNSS augmentation service (GRAS) will support gate-to-gate operation throughout the coverage area.

The results from NEAP will be made known to various standardisation bodies such as ICAO Panels and EUROCAE.

Seminars and workshops along with exhibitions at different locations are also planned.

Despite the official termination of the project, the NEAP applications and services will continue to operate until further in order to allow the Partners to gain more experience and collect additional evaluation data. Ground and airborne equipment used in NEAP will be used in other EU and Eurocontrol projects such as FREER (free flight...
scenarios) and the PETAL II (controller-to-pilot data link communication). Co-ordination of European ADS-B activities will be intensified in, for instance, Eurocontrol’s ADS programme, NUP and FARAWAY. Operational implementation is possible without awaiting the development of international standards for individual applications that do not require interoperability with other systems. At Stockholm-Arlanda Airport a system employing STDMA/VDL Mode 4 and ADS-B is being implemented for support of snow clearing operations.