Roadmap for the implementation of data link services in European Air Traffic Management (ATM):

Datalink roadmap

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Author	Helios Technology, Sofreavia, IATA, Integra Consult, Airbus
Produced by	Helios Technology Ltd Chamberlain House High Street Bagshot Surrey GU19 5AE Tel: +44 1276 452 811 Fax: +44 1276 472 897
Produced for	European Commission Directorate-General Energy and Transport
Helios contact	Mike Shorthose Tel: +44 1276 452 811 Fax: +44 1276 472 897 Email: mike.shorthose@helios-tech.co.uk
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AUTHORITY	NAME AND SIGNATURE	DATE
Helios Project Manager	Mike Shorthose	
Integra Project Manager	Dorte Wang	
IATA Project Manager	Nicolas Zveguintzoff	
Sofréavia Project Manager	Nga Bui	
Airbus Project Manager	Thomas Fixy	

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Executive Summary

This document describes a roadmap for the implementation of data link services in European ATM and has been produced during Phase 2 of a study for the European Commission. The work has been carried out under contract B2001/B2 – 7020B/S12.330694.

Additional information can be obtained from other detailed reports produced during the study as follows:

- "Executive Summary", P167D017, version 1.0, 28th February 2003. This document contains an executive summary of the findings of the study.
- "Application Assessment", P167D1030 version 2.0, 30 October 2002. This document presents the results of Phase 1 which focussed on the identification, characterisation and selection of ATM applications. The document establishes initial timescales for each of the ATM applications and records stakeholder comments on the work carried out in Phase 1.
- "Non-ATS applications", P167D1050 version 1.0, 28 February 2003. This document presents the results of a summary of requirements for non-ATS applications.
- "Technology Assessment", P167D2020 version 5.0, 28 February 2003. The documents presents the results of the assessment of data link technologies carried out in phase 2 of the study. The document is subdivided as follows:
  - The main body of the report summarises the technology assessment, scenario analysis and technology selection.
  - The annexes of the report describe each of the technologies considered in the study as well as the overall network architecture and cost assessment.
- "References", P167D3030 version 3.0, 28 February 2003. This sets out the references used in the study.
- "Phase 2 Consultation", P167D016 version 1.0, 28th February 2003. This document contains proceedings of the Second Stakeholder Workshop held on the 21st February 2003 and comments received on the Phase 2 deliverables.

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1 Introduction

1.1 Purpose of this document

1.1.1 This document has been produced during Phase 2 of a study for the European Commission to develop a roadmap for the implementation of data link services supporting air traffic management (ATM) applications in Europe. The work has been carried out under contract B2001/B2 – 7020B/S12.330694.

1.1.2 This study is an independent assessment of different candidate data link technologies with the aim of proposing the most suitable data link(s) in support of the European decision-making process. To achieve this, Phase 1 of the study established a tentative list of ATM applications particularly suited for enhancing safety and capacity. These ATM applications are based on the definition of medium and long-term objectives in air traffic management.

1.1.3 The list of ATM applications identified during Phase 1 of the study was reviewed extensively by Stakeholders and agreement was reached as to the priority and timescales for each ATM application.

1.1.4 Phase 2 of the study has focussed on the assessment of candidate data link technologies taking account of factors such as the ability to meet the technical requirements of the ATM applications, maturity and cost. The results of the detailed technology assessment are contained in document P167D2020. These results were used to make a selection of suitable data link technologies to achieve the objectives of the ATM applications, to place the implementation of the technologies on a roadmap and to identify actions and Community measures necessary to support the successful implementation of the roadmap.

1.1.5 The purpose of this document is present the overall results of Phase 2 and, in particular, to present the combined ATM application and data link technology roadmap.

1.2 Consultation

1.2.1 A public consultation process was held between December 2002 and February 2003, culminating in the second stakeholder workshop held on the 21st February 2003.

1.2.2 This document has been updated to reflect the comments received. Details of the workshop discussion and written comments are provided in P167D017.

1.3 Consensus forming and the way ahead

1.3.1 Whilst it was the intention of the study to reach consensus on the choice of data links, this was not achieved because some of the data required for such a choice was, and still is missing. Significant “pockets” of consensus were obtained for particular solutions. This summary documents the level of consensus and defines further actions to assist the community in resolving open issues.

1.3.2 It is understood that the results of the study will feed into an industry consultation group to be established by the European Commission within the terms of the Single Sky legislation. However time is of the essence and the Consortium urges the Commission to ensure that all actions will be undertaken as soon as possible.

1.4 Contents of the document

1.4.1 This document consists of:

- In section 2, a description of the approach used in the study.
- In section 3, a summary of the ATM application roadmap, organised according to a series of five key implementation steps.
- In section 4, a summary of the technology assessment and selection process including a summary of the technology baseline (ie the status of technology implementation now) and identification of the selected technologies.
- In section 5, a detailed description of the selected data link technologies.
- In section 6, an estimation of the costs and benefits associated with the roadmap.
- In section 7, Community measures specifying an action plan for the activities required by the various stakeholders for the successful implementation of the roadmap.
- In section 8, a summary of the actions required to support the roadmap.

1.4.2 A list of acronyms used in the report is provided in section 9.

1.4.3 This document is intended to provide a stand-alone summary of the key conclusions of the entire study. Additional information can be obtained from other detailed reports produced during the study as follows:

- "Application Assessment", P167D1030 version 2.0, 30 October 2002. This document presents the results of Phase 1 which focussed on the identification, characterisation and selection of ATM applications. The document establishes initial timescales for each of the ATM applications and records stakeholder comments on the work carried out in Phase 1.
- "Non-ATS applications", P167D1050 version 1.0, 28 February 2003. This document presents the results of a summary of requirements for non-ATS applications.
- "Technology Assessment", P167D2020 version 5.0, 28 February 2003. The documents presents the results of the assessment of data link technologies carried out in phase 2 of the study. The document is subdivided as follows:
    - The main body of the report summarises the technology assessment, scenario analysis and technology selection.
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- "References", P167D3030 version 3.0, 28 February 2003. This sets out the references used in the study.

2 Approach

2.1 Terminology used in the study

2.1.1 Figure 2-1 illustrates the relationship between ATM applications and technical requirements:

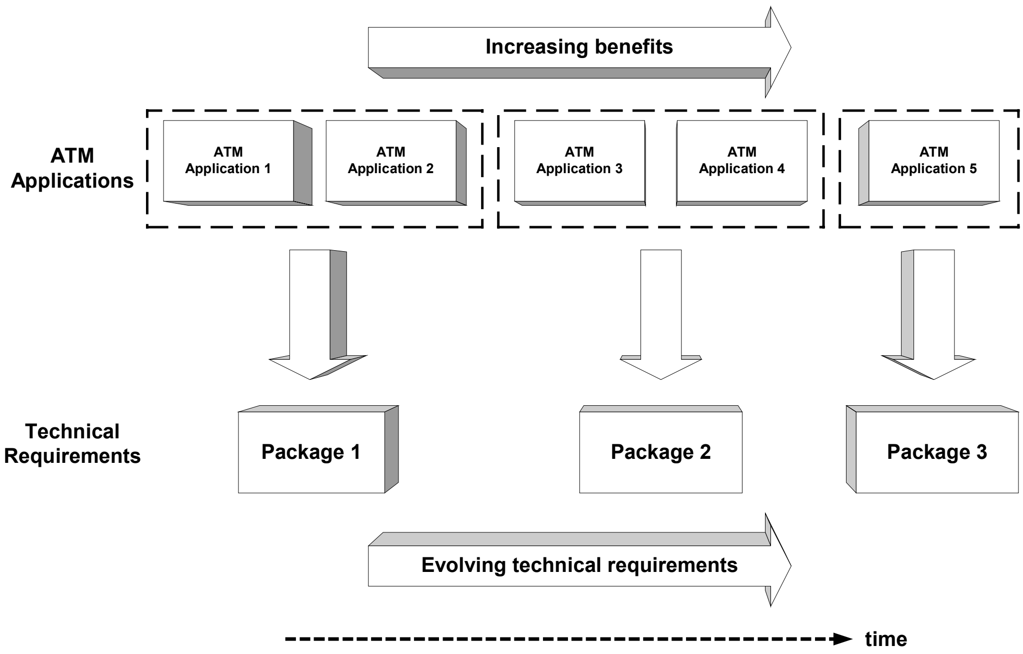

Figure 2-1: Evolution of ATM applications and technical requirements

2.1.2 The term "ATM application" is used to represent a change to the way in which air traffic management is carried out. The change might be to the control procedures, perhaps involving delegation of some tasks to the pilot, or to the way in which current services are provided, such as automating some current tasks or providing an alternative method of obtaining essential information such as a surveillance picture. Each ATM application has the potential to provide benefits in one or more airspace regions. Therefore ATM applications, and their evolution in time, have been used in the study as a focus for the assessment of benefits.

2.1.3 "Technical requirements" describe data link characteristics necessary to support the ATM applications. At a high level, these consist of the interpretation of the operational communication characteristics of ATM applications onto technical communication characteristics. At a lower level, performance requirements (range, integrity, connectivity, etc) are defined. The technical requirements, and their evolution in time, provided the focus for the technology assessment.

2.2 Phase 1 approach

2.2.1 The following work was carried out in Phase 1 of the study:

- Identification of the ATM applications that require communication services and that could be implemented within European airspace in the period up to 2015.
- Assessment of which ATM applications offer most benefit to stakeholders.
- Analysis of the implementation constraints and their impact on the timescales for realisation of each ATM application.
- Selection of those ATM applications which provide the best balance between benefits and implementation constraints.
- Proposal of an initial timeline for the implementation of the ATM applications.
- Provision of technical requirements for the data links required to support the ATM applications in the period up to 2010 taking account of the need to prepare for a later extension of the data link infrastructure in the period 2010 to 2015.
- Consultation to obtain stakeholder endorsement of the selected ATM applications, the initial timeline and the technical requirements.
- Establishment of an assessment framework used to evaluate candidate technologies in Phase 2.

2.3 Phase 2 approach

2.3.1 The following work was carried out in Phase 2:

- Technology Assessment: Each technology was assessed individually in terms of:
  - Technical assessment - consideration of the general characteristics and services supported by the media, including:
    - Capability assessment - detailed description of the technical strengths and weaknesses of the media.
    - Maturity assessment - consideration of when the media could be deployed by analysis of simulations and trials activities, standards maturity, equipment development and system deployment.
    - Complexity assessment - assessment of airborne and ground architectures including complexity of proposed solutions.
  - Cost assessment: Assessment of relative cost of each technology.
  - Industrial assessment: Assessment of stakeholder, avionics manufacturer and aircraft manufacturer support for the technologies.

  The technology assessment is contained in Annexes D to P of P167D2020.

- Technology Selection: The capabilities of the datalink technologies were compared to the requirements established in Phase 1 and recommendations for potential roles in the datalink roadmap developed.
- Scenario Selection: A number of potential scenarios were postulated from the identified roles for each technology. A multi criteria analysis was then performed to select the most appropriate scenario for the datalink roadmap. The criteria use were:
  - ability to deliver the ATM application roadmap;
  - overall cost;
  - availability of required frequencies;
  - global interoperability;
  - support for evolving requirements for ATC voice;
  - support for evolving requirements for non-ATS data.
- Development of the data link technology roadmap. This consisted of:
  - development of plan, or “roadmap” for the phased introduction of the technologies retained during the technology assessment;
  - estimation of the costs and benefits delivered by the roadmap;
  - identification of Community actions required to support the roadmap.

3 Summary of ATM application roadmap

3.1 Introduction

3.1.1 An ATM application roadmap was derived as a result of the analysis carried out in Phase 1 of the study.

3.1.2 The ATM application roadmap presented in this section is based on:

- Timescales taken directly from Phase 1 results. These timescales represent when an ATM application is required in order to deliver benefits in a timely manner.
- Modification to timescales resulting from constraints identified during technology assessment. Note that the analysis carried out in Phase 1 took account of an initial analysis of when it would be practical to implement an ATM application given the constraints of providing ground and airborne infrastructure. However, the impact of technology availability was not taken account of during phase 1 but has been considered when reassessing the timescales in Phase 2.

3.1.3 It is recognised by the study team that maintenance or enhancement of safety is central to the provision of ATM. However, another important driver, which offsets the necessary costs of investment in new infrastructure relates to the provision of additional capacity. Without additional capacity, the results of phase 1 indicate that the cost of delays and failure to accommodate demand will lead to rapidly escalating costs for the industry.

3.1.4 Phase 1 of the study therefore derived an ATM application roadmap which has the potential to deliver sufficient capacity to meet future demand. Emphasis has been placed on spacing and separation ATM applications in en-route airspace. For terminal areas, the study team believe that the main capacity enhancing step is the use of trajectory prediction provided by ground systems for setting arrival times into the terminal areas.

3.1.5 It is recognised that the most urgent area for capacity enhancement is terminal airspace where capacity restrictions already result in considerable service disruption. However, the view of the study team is that it is also important to make progress on en-route capacity provision: the goal here is to facilitate en-route growth while keeping the cost of the infrastructure, and particularly the number of en-route sectors, at current levels. As traffic grows, this in itself leads to a significant reduction in costs per flight and provide benefits which can be applied to developments in the terminal areas where the necessary investment to obtain capacity enhancements is likely to be higher than for en-route.

3.1.6 The Phase 1 analysis results in the delivery of capacity in 5 steps:

- Step 1: early a/g ATM applications;
- Step 2: ATM applications related to downlink of air-derived data;
- Step 3: introduction of spacing;
- Step 4: extension of a/g ATM applications;
- Step 5: introduction of separation, self-separation and conflict free trajectory negotiation.

3.2 Step 1: early a/g ATM applications

3.2.1 Step 1 provides the implementation of the following ATM applications:

- **APP2b: strategic controller/pilot messages.** This includes downstream clearances for oceanic, information on Standard Arrivals (STARS), and strategic clearances using the controller/pilot data link communications (CPDLC) data link application.
- **APP4a: Provision of D-OTIS (automatic terminal information service (ATIS), Meteorological Report (METAR) and D-RVR[1]).** This ATM application concerns automation of services that are currently delivered by voice[2].

3.2.2 Step 1 also includes **APP14b: ATS in oceanic/remote areas.** This includes CPDLC services and surveillance via ADS-contract (ADS-C). ADS-C offers the opportunity to obtain greater situational awareness in oceanic airspace. ADS-C is able to provide regular position reports, position reports on demand from the controllers and position reports following an event (for example, an aircraft crossing a waypoint). CPDLC provides, for example, clearance delivery. The combination of CPDLC and ADS-C is expected to enable more efficient climb/descent and passing manoeuvres and more efficient lateral passing manoeuvres.

3.2.3 These ATM applications require an aircraft/ground point to point data link in addition to the following adaptations to the current infrastructure:

- adaptation to CWP and related ground systems, including:
  - adaptation of controller interface and tools;
  - update of the ground systems to support the processing of the information eg new terminal to provide uplink information;
  - implementation of a capable ground network..
- adaptation to cockpit including update of cockpit suites and onboard networks.

3.2.4 The following benefits will be delivered by Step 1:

- terminal and en-route capacity benefits of typically 11% [20];
- safety benefits arising from reduced risk of misunderstanding between controllers and pilots;
- flight efficiency benefits particularly in the oceanic region;
- enabling benefits in preparation for later steps which use aircraft/ground data links.

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[1] D-RVR is not part of the Link2000+ program. Comments were received during the public consultation to the effect that D-RVR should be considered as part of Step 4 and not Step 1.

[2] Some parts of this ATM application have already been implemented like D-ATIS over ACARS.

3.3 Step 2: ATM applications related to downlink of air-derived data

3.3.1 Step 2 provides the implementation of the following ATM applications:

- APP1a: Enhanced surveillance in terminal and en route airspace, limited additional information being displayed to the controller. This ATM application has been selected to map closely with the proposals for an initial package of controller access parameters (CAPs)
- APP1b: Enhanced surveillance in terminal and en-route airspace providing a wider range of DAPs. Provision of downlinked data to increase the efficiency for tactically separating aircraft.
- APP1c: Enhanced surveillance accuracy for automation tools in terminal and en-route airspace. This ATM application covers the system wide use of DAPs.

3.3.2 The following types of data link could support these ATM applications:

- Mode S secondary surveillance radar;
- aircraft to ground broadcast data link;
- air-ground datalink supporting ADS-C.

3.3.3 In addition to current infrastructure this step will require:

- adaptation to CWP and related ground systems, including:
  - controller user interface for display of enhanced track data/RDP (incorporation of air-derived data)/ground network update;
  - controller support tools (e.g. automatic warning, trajectory predictor), RDP (incorporation of air derived data);
  - greater integration with FDP and CFMU (potential use of intent data);
  - ground network update to provide ADD data from surveillance sensors.
- adaptation to airborne systems including integration with onboard data.

3.3.4 The following benefits will be delivered by Step 2:

- Terminal and en-route capacity benefits of typically 27% [P167D1030] in addition to the benefits associated with step 1.
- Safety benefits arising from provision of more precise information making it possible to enhance tracking and safety net tools. For example the UK propose using downlinked data to reduce false alarms from safety monitoring systems resulting from perceived level busts. Downlinked information facilitates priority, special handling or declaring an emergency. In terminal area, benefits include conformance monitoring during simultaneous parallel and converging approaches. For example, France intends to use heading information on parallel approaches.
- Improvement of flight efficiency is made possible by allowing for more anticipation in traffic planning.

3.3.5 Step 2 also allows for the validation of the use of DAP on the ground by testing the impact of downlinked parameters on ground systems. Support of other ATM applications relying on the use of advanced automated controller tools (e.g. Arrivals Manager (AMAN), Departure Manager (DMAN), MTCD (Medium Term Conflict Detection), Surface Management) that are improved using additional aircraft data.

3.3.6 Depending on the technology choice, Step 2 also provides the opportunity to save ground infrastructure costs through the use of ADS-B technology rather than some of the secondary surveillance radar. The specific ATM applications are:

- **APP1d: Fusion of current radar and ADS-B surveillance in terminal and en-route airspace.** The purpose of this ATM application is to provide a means for achieving multiple coverage in an environment where radar is mixed with ADS-B surveillance.
- **APP13a: Fusion of current terminal and/or surface radar with other surveillance means.** This provides enhanced surveillance accuracy for terminal automation tools.

3.3.7 Step 2 also has the potential to delivery additional benefits through the avoidance of the costs of upgrading part of the ground infrastructure to Mode S enhanced surveillance.

3.4 Step 3: introduction of spacing

3.4.1 Step 3 provides the implementation of the following ATM applications which introduce spacing into the en-route and terminal environment:

- **APP9a: Airborne spacing in en-route and terminal airspace.** This includes establishing in-trail spacing intervals, level spacing and in-descent spacing in core and transitional en-route and terminal airspace.
- **APP9b: Crossing and passing in en route airspace.** This includes level crossing and passing and vertical crossing in core and transitional airspace.
- **APP9c: Final approach spacing.** This is also known as improved approach spacing (CDTI enhanced flight rules) [115]. Aircraft establish and maintain separations in the approach path. Benefits arise because aircraft have the potential to maintain a separation that is closer to the allowed minimum [38].
- **APP9d: Departure spacing.** Currently departure spacing is generally controlled on a time basis: the time between departures depending on the whether the aircraft will follow or diverge from the preceding aircraft. The result of current operational practice is that aircraft tend to enter terminal airspace at separations that greatly exceed the allowed minimum. Departure spacing using ADS-B has the potential to involve the pilot in collaborative decision making for take off time based on a distance behind the preceding aircraft with the potential to achieve closer separations at the terminal area boundary [38].

3.4.2 The following data link will be required to support these ATM applications:

- Ground to aircraft broadcast data link and associated TIS-B network. It is expected that the provision of TIS-B data from the existing surveillance system will be provided over a “wide area” en-route region. Note that it is potentially easier to provide TIS-B in approach and departure environment.[3]

3.4.3 In addition, adaptation will be required to the cockpit and airborne systems including:

- implementation of airborne surveillance function (additional connections with the FMC for ADS data);
- CDTI;
- traffic information processing function and airborne spacing functions (to provide the spacing information to the pilot and specific alerts);
- airborne surveillance processing system (fusion of TIS-B and ADS-B data), integration with navigation equipment.

3.4.4 It is assumed that only minimal changes to the CWP will be required to support spacing.

3.4.5 The following benefits will be delivered by Step 2:

- terminal and en-route capacity benefits of typically 9% [P167D1030].
- enabling benefits preparing for Step 5a.

3.4.6 This step also provides a significant level of safety benefits through implementation of the following ATM applications:

- **APP3a: Enhanced visual acquisition (EVA) in remote and oceanic airspace.**
- **APP3b: Enhanced visual acquisition (EVA) in terminal airspace.**
- **APP3c: Enhanced visual approaches.**
- **APP3d: Traffic situational awareness in core and transitional en-route airspace.** This includes a package of ATM applications: EVA, Enhanced Traffic Information Broadcast (E-TIBA) and Enhanced See and Avoid (E-S&A).
- **APP12a: Surface enhanced visual acquisition.** This is also known as airport surface situational awareness (Visual Flying Rules (VFR) -day and VFR-night) and is expected to provide smoother taxiing in good weather via providing better awareness to the pilots, eliminating some of the constraints imposed by the limited visibility from the cockpit.
- **APP12b: Runway and final approach occupancy awareness.** Provides enhanced awareness of other aircraft and vehicles on the airport surface reducing the risk of runway incursions.
- **APP12c: Enhanced IMC airport surface operations.** This is similar to surface enhanced visual acquisition (APP12a) but enhances operations in reduced visibility supporting, in particular, landing and take-off and possibly taxi operations.

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[3] Airbus have indicated that whilst TIS-B is conceptually attractive it has not been validated. Further work is required to define the operational and technical requirements for TIS-B.

3.4.7 These ATM applications lead to an increase in safety levels by supporting positive identification of traffic, reducing mis-identification of aircraft and earlier anticipation of collision risks. The benefits are most effective in high traffic density complex areas or where the quality of ATS is poor (ie lack of ground surveillance).

3.4.8 Enhanced visual acquisition is expected to provide [115]:

- better establishment of visual contact and positive identification of aircraft, even if more than one aircraft is visible;
- reduced time to establish visual contact to other aircraft;
- improved crew capability of assessing the distance to a preceding aircraft and for keeping a certain distance from it, even at changing speed and/or heading;
- reduced probability of a go-around for parallel approaches (loss of visual contact);
- repeated positive identification of the target in high traffic density conditions.

3.4.9 This group of ATM applications also supports capacity enhancement under marginal VMC conditions in terminal airspace.

3.5 Step 4: extension of a/g ATM applications

3.5.1 Step 4 provides the implementation of the following ATM applications which extend the range of aircraft/ground data link services:

- **APP2a: Pilot preferences data link.** Downlink of a pilot's preferred routing.
- **APP2c: Support for increased automation.** This provides a full range of data link services which provide increased automation. In particular, this includes strategic ATM exchanges such as strategic collaborative flight plan exchanges relying on data link services such as FLIPCY and DYNAV.
- **APP4b: Provision of full range of uplink information services.** This provides services that are not currently available to the pilot and includes automatic Operation Flight Information Service (OFIS), which will be derived from NOTAM/ Snow Alert (SNOWTAMS) information, SIGMET.
- **APP7a: Provision of information on route availability (DYNAV)**. In addition to an uplink of information on available routes, it is expected that this ATM application will require at least part of the services provided for the PPD ATM application in order to provide efficient coordination with ground systems.
- **APP13c: Routing.** This provides routing information such as taxi clearances to aircraft on the airport surface.

3.5.2 This step requires an aircraft/ground point to point data link in addition to the following adaptations to the current infrastructure:

- adaptation to CWP and related systems including:
  - further development of interface and networks established during step 2.
  - a considerable change in current ground FDP systems to provide the ability to handle changes to aircraft flight plans in real time.
- adaptation to cockpit and airborne systems including update of the interface to display the uplink message content.

3.5.3 The following benefits will be delivered by Step 4:

- terminal and en-route capacity benefits of typically 8% [P167D1030];
- safety benefits arising from reduced risk of misunderstanding between controllers and pilots;
- enhanced flight planning through the provision of uplink information;
- enabling benefits in preparation for later steps which use aircraft/ground data links.

3.6 Step 5: introduction of separation, self-separation and conflict free trajectory negotiation

3.6.1 This step is divided into two:

- Step 5a providing for the introduction of separation and self-separation
- Step 5b providing for the introduction of conflict free trajectory negotiation.

3.6.2 The sub-division is proposed because it is not clear at this stage what will be the balance between them in the future ATM system:

- the phase 1 report concluded that in en-route, it is important to provide separation and self-separation and a means to increase capacity whereas in terminal regions, planned arrival times are more important (predicated on genuine 4D navigation noting that it is unlikely that operators will implement 4D RNAV until at least 2015)
- other opinion (eg Eurocontrol) are not yet decided on this balance and are in the process of evaluating both concepts
- the possibility that both concepts are implemented, Step 5b for the core area and Step 5a for less dense areas where flight efficiency rather than capacity is required.

3.6.3 Step 5a provides the implementation of the following ATM applications introduce separation and self-separation:

- **APP10a: Airborne separation in oceanic and remote airspace.** This includes in-trail climb (ITC), in-trail descent (ITD), lateral passing manoeuvres and station keeping.

- **APP10b: Airborne separation in en-route and terminal airspace.** This includes following, crossing and climb/descent manoeuvres, sequencing applications.
- **APP10c: Final approach separation.** This includes pair approaches and is the progression of APP9c but makes possible reduced approach spacings.
- **APP11a: Cluster control in ATC managed airspace.** This will apply in core and transition airspace. In Cluster control the pilot is provided with surrounding traffic information (state + trajectory intent)
- **APP11b: Autonomous operations in FFAS.** This is expected to apply initially in remote or transitional en-route airspace and then later to high density airspace.

3.6.4 Step 5b provides the implementation of the following ATM applications:

- **APP2d: Trajectory negotiation.** This provides strategic ATM exchanges such as tactical collaborative flight plan exchanges relying on COTRAC data link services.

3.6.5 It is expected that the following types of data link will be required to support Steps 5a and 5b:

- Aircraft to aircraft broadcast data link with sufficient integrity to support autonomous operations.
- Aircraft to aircraft point to point data link: For APP10b and APP10c there may be a need to use as a means of target designation. May also be required for APP10a to maintain communication if the airborne surveillance picture is lost.
- Enhanced aircraft/ground point to point data link supporting tactical real time data transfer.

3.6.6 In addition the following adaptations will be required:

- CWP adaptation and related ground systems including:
  - support for integrated planning and trajectory negotiation, impacting on FDP and CFMU as well as control suite;
  - provision of controller tools to support separation including separation infringement alerts;
  - implementation of a capable ground network required.
- adaptation to cockpit
  - enhanced cockpit equipment to support trajectory negotiation and separation functions (target designation, separation infringement alerts etc).

3.6.7 Step 5 has the potential to deliver a considerable step in capacity. The Phase 1 report concluded that separation can contribute around 39%, whereas self-separation adds an additional 50%. It should be emphasised that more research is needed to establish if these figures are feasible. Similarly APP2d has the potential to increase capacity through provision of conflict-free trajectory planning. The step will also enhance flight efficiency through provision of more optimum trajectories.

3.6.8 In addition, the availability of a capable ADS-B link will facilitate ATM applications that rely on ADS-B as the sole surveillance means:

- **APP1e: Air traffic control (ATC) surveillance using ADS-B in terminal and en-route airspace.** The purpose of this ATM application is to provide surveillance coverage by ADS-B technology alone. The scope of APP1e is limited to terminal and en-route regions. Provision of surveillance coverage by a similar means in airport and remote regions is covered by APP13b and APP14a respectively.
- **APP13b: ATC surveillance using aircraft information at airports.** This enables application of pseudo radar separation standards at airports without radar coverage
- **APP14a: Basic surveillance infrastructure via ADS-B in remote regions.** ADS-B offers the opportunity to provide a basic surveillance picture to ground controllers without the need to provide radar infrastructure.

3.7 ATM application roadmap summary

3.7.1 The following tables summarise the steps of the ATM application roadmap in terms of the ATM applications, D/L services and requirements categories for each of the four considered regions[4].

Step	ATM Applications	D/L Services	Requirements Category
1	APP2b– Strategic controller/pilot messages	DLIC DCL ACL ACM	CPDLC-0
	APP4a – Provision of terminal (automatic terminal information service, meteorological report) and runway information	D-ATIS METAR D-RVR	D-FIS-0
2	APP13a – Fusion of current terminal/surface radar with other surveillance means	ADS-B	ADS-B-S0
3	APP12a – Surface enhanced visual acquisition APP12b – Runway and final approach occupancy awareness APP13b – ATC surveillance using ADS-B at airports APP12c – Enhanced IMC airport surface operations	ADS-B	ADS-B-S1
4	APP4b – Provision of full range of uplink information services	NOTAM SNOWTAM D-SIGMET	D-FIS-0
4	APP13c – A-SMGCS Routing	ACL	CPDLC-3

Table 3-1: ATM application roadmap for surface operations

[4] D/L Services and Requirements Category are defined in P167D0140.

Step	ATM Applications	D/L Services	Requirements Category
1	APP2b – Strategic controller/pilot messages	DLIC ACL ACM DCL DSC	CPDLC-0
	APP4a – Provision of terminal (automatic terminal information service, meteorological report) and runaway information	D-ATIS METAR D-RVR	D-FIS-0
2	APP1a – Limited Enhanced Surveillance in terminal and en-route airspace APP1b – Enhanced Surveillance in terminal and en-route airspace providing a wider range of DAPS APP1c – Enhanced Surveillance accuracy for automation tools in terminal and en-route airspace	CAP SAP	ADAP-1
	APP1d – Fusion of current radar and ADS-B surveillance in terminal and en-route airspace	ADS-B	ADS-B-A-0
3	APP3b – Enhanced Visual Acquisition in terminal airspace APP3c – Enhanced Visual Approaches	ADS-B TIS-B	ADS-B-A0
	APP9a – Airborne Spacing in en-route and terminal airspace APP9c – Final Approach Spacing APP9d – Departure Spacing	ADS-B TIS-B	ADS-B-A1
4	APP2a – Pilot Preferences Datalink	PPD	ADAP-0
	APP2c – Support for increased automation APP7a – Provision of information on route availability	FLIPCY DYNAV	CPDLC-2
	APP4b – Provision of full range of uplink information services	NOTAM SNOWTAM D-SIGMET	ADAP-0
5a	APP1e – ATC Surveillance using ADS-B in terminal and en-route airspace	ADS-B	ADS-B-A2
	APP10b – Airborne Separation in en-route and terminal airspace APP10c – Final Approach Separation	ACL	CPDLC-1
5b	APP2d – Trajectory Negotiation	COTRAC FLIPCY FLIPINT	CPDLC-3

Table 3-2: ATM application roadmap for terminal operations

Step	ATM Applications	D/L Services	Requirements Category
1	APP2b – Strategic controller/pilot messages	DLIC ACL ACM DSC	CPDLC-0
2	APP1a – Limited Enhanced Surveillance in terminal and en-route airspace APP1b – Enhanced Surveillance in terminal and en-route airspace providing a wider range of DAPS APP1c – Enhanced Surveillance accuracy for automation tools in terminal and en-route airspace	CAP SAP	ADAP-1
	APP1d – Fusion of current radar and ADS-B surveillance in terminal and en-route airspace	ADS-B	ADS-B-A0
3	APP3d – Traffic Situational Awareness in core and transitional airspace	ADS-B TIS-B	ADS-B-A0 TIS-B-0
	APP9a – Airborne Spacing in en-route and terminal airspace APP9b – Crossing and passing in en-route airspace	ADS-B TIS-B	ADS-B-A1 TIS-B-1
4	APP2a – Pilot Preferences Datalink	PPD	ADAP-0
	APP2c– Support for increased automation APP7a – Provision of information on route availability	FLIPCY FLIPINT DYNAV	CPDLC-2
	APP4b – Provision of full range of uplink information services	NOTAM SNOWTAM D-SIGMET	ADAP-0
5a	APP1e – ATC Surveillance using ADS-B in terminal and en-route airspace APP10b – Airborne Separation in en-route and terminal airspace	ADS-B TIS-B	ADS-B-A2 TIS-B-2
		ACL	CPDLC-1
	APP11a – Cluster Control in ATC Managed Airspace	ADS-B	ADS-B-A2
		ACL	CPDLC-1
5b	APP2d – Trajectory Negotiation	COTRAC FLIPCY FLIPINT	CPDLC-3

Table 3-3: ATM application roadmap for en-route and transition applications

Step	ATM Applications	D/L Services	Requirements Category
1	APP14b – ATS in oceanic and remote regions	ADS-C	ADS-C-1
2	APP14a – Basic Surveillance Infrastructure via ADS-B in remote regions	ATSAW ADS-B	ADS-B-A2
3	APP3a – EVA in remote and oceanic airspace	ADS-B	ADS-B-A0
4	APP4b – Provision of full range of uplink information services	NOTAM SNOWTAM D-SIGMET	ADAP-0
	APP7a – Provision of information on route availability	DYNAV	CPDLC-2
5a	APP10a – Airborne Separation in Oceanic and Remote Airspace	ADS-B TIS-B	ADS-B-A2 TIS-B-2
		ACL	CPDLC-1
	APP11b – Autonomous Operations in FFAS	ADS-B	ADS-B-A2
		PPDLC	AADE-0
		ACL	CPDLC-1
5b	APP2d – Trajectory Negotiation	COTRAC FLIPCY FLIPINT	CPDLC-3

Table 3-4: ATM application roadmap for oceanic and remote operations

3.8 Operational dates and related OIs

3.8.1 Figure 3-1 below shows operational dates for the ATM applications. The target period for related SPF Operational Improvements [256] are also shown.

3.8.2 The timescales are based directly on the Phase 1 results modified where necessary by the following technology constraints identified during Phase 2:

- the earliest estimated date for ADD equipage delays implementation of ATM applications associated with Step 2 by approximately 6 months.
- production of applications standards for EVA and spacing ATM applications delayed by approximately 1 year noting that standards are not expected to be complete before mid-2004.

3.8.3 Operational dates were defined in P167D1030 as the date where there is widespread usage of an ATM application. Within Phase 2, this has been interpreted as the date when 75% of aircraft are equipped with the necessary technology and 75% of the ground systems support the ATM application.

ID	Info	Task Name	Date
778		**Operational**	
779		**Step 1: early a/g ATM applications**	
780		APP2b Operational	28/12
781		APP4a Operational	27/01
782		APP14b Operational	26/09
783	030402	Use Data Link to Improve Efficiency of Communications	
784	040202	Enhancement of Airport Operations through Information Exchange between ATC, A	
785	040301	Enhancement of Aerodrome Operations Through Arrival Management	
786	040302	Enhancement of Aerodrome Operations Through Departure Management	
787		**Step2: ATM applications related to ADD**	
788		APP1a Operational	28/12
789		APP1b Operational	27/06
790		APP1c Operational	27/06
791	030102	Use Aircraft Derived Data for Ground Based Safety Nets	
792	030403	Automatic Provision of Airborne Data to Enhance Ground Systems Functions includi	
793	030201	Provide Automated Support for Conflict Detection	
794	030202	Provide Automated Support for Conflict Resolution	
795	030203	Provide Automated Support for Traffic Complexity Reduction	
796	030204	Enhance ATC Decision Support by Using Aircraft Derived Data	
797		APP1d Operational	22/03
798		APP13a Operational	22/12
799	040102	Improvement of Conflict Detection and Alert for the Movement Area	
800		**Step 3: introduction of spacing**	
801		APP3a Operational	25/12
802		APP3b Operational	29/06
803		APP3c Operational	18/07
804		APP3d Operational	25/12
805	030501	Provide Airborne Traffic Situational Awareness	
806		APP9a Operational	31/08
807		APP9b Operational	31/08
808		APP9c Operational	26/06
809		APP9d Operational	31/08
810		APP12a Operational	04/03
811		APP12b Operational	04/03
812		APP12c Operational	24/11
813	040204	Optimisation of Airport Operations in All Weather Conditions	
814		**Step 4: extension of a/g ATM applications**	
815		APP2a Operational	28/01
816		APP7a Operational	28/01
817		APP4b Operational	30/03
818		APP2c Operational	21/09
819		APP13c Operational	21/09
820	040103	Improvement of Planning and Routing	
821	040104	Improvement of Guidance and Control	
822	040203	Airport Collaborative Information Exchange Including Gate Management	
823		**Step 5a: introduction of separation/self-separation**	
824		APP10a Operational	21/09
825		APP10b Operational	17/06
826		APP10c Operational	17/06
827	030502	Delegate Separation Service	
828	030504	Empower Autonomous Aircraft Operations	
829	060102	Improved airborne safety nets	
830		APP11a Operational	09/09
831		APP11b Operational	09/09
832		APP14a Operational	30/12
833		**Step 5b: introduction of conflict free trajectory negotiation**	
834		APP2d Operational	01/07
835	030503	Facilitate User-preferred 4-D Trajectory	
836	040303	Enhancement of Aerodrome Operations Through Fully Integrated Arrival, Departure	
837	040304	Further Enhancement of Aerodrome Operations from Gate to Gate	
838		APP1e Operational	16/09
839		APP13b Operational	18/06

Figure 3-1: Operational dates for ATM applications

3.8.4 The ATM application roadmap provides a good match to the timing of operational improvements noting that:

- Step 2 ATM applications are not likely to be supported until the OI period 2 – the delay is associated with obtaining sufficient airborne equipage.
- There is no equivalent OI for spacing applications although the timing of the spacing ATM applications is compatible with the need to provide a confidence building period prior to the implementation of separation.

3.8.5 Note that Airbus expectations for when ATM applications are supported, based on its own equipage plans and its perception of when ANSPs will be ready to support the new ATM applications, are different to those contained in the roadmap. The differences are as follows:

- Step 2: 2006 (cf 2008)
- Step 3: EVA from late 2007 (as per roadmap). Spacing 2012 (cf 2010) except final approach spacing 2008 (cf 2007). It is assumed that EVA and final approach spacing will be supported on current cockpit displays whereas en-route spacing will require new or substantially modified displays.
- Step 5a: Airborne separation in oceanic and remote airspace 2012 (cf 2010), en-route and terminal separation 2018 (cf 2015)
- Step 5b: 2011 (cf 2015)
- Surveillance based on sole means ADS-B (APP1e/APP13b) 2017 – 2019 (cf 2013 – 2014).

3.8.6 Broadly speaking, ADD ATM applications in step 2 are expected to be implemented earlier than the Phase 1 timescales whereas as all ATM applications which rely on ADS-B (spacing, separation, sole means surveillance) are considerably later. Furthermore, ATM applications supporting conflict-free trajectories in Step 5b are considerably earlier. The impact of this difference in emphasis is discussed later in this document and is also highlighted as a topic of discussion for the stakeholder consultation phase.

4 Technology Assessment

4.1 Selected Technologies

4.1.1 Classification

4.1.1 This section identifies the technologies that have been considered as candidates in the timeframe to 2015. The technologies are presented according to the following classification:

- Current technologies are those which are already in operation.
- Technologies for which significant deployment decisions have been taken.
- Emerging technologies are those that have been subject to significant development work by the aviation community.
- Future technologies are those for which there are emerging development plans.

4.1.2 The current technologies together with those for which significant deployment decisions have been taken were used as the baseline for the technology selection process.

4.1.2 Current technologies

4.1.2.1 The current technologies for the study are those which are already in operation or which have been mandated:

- ACARS datalink for AOC supported by VHF, HFDL and AMSS;
- FANS1/A supported by AMSS and VHF;
- Voice supported by 25kHz and 8.33 kHz;
- Mode A/C Secondary Surveillance Radar in ECAC;
- Mode S Elementary Surveillance in 2005 (mandate announced in AICs issued by Belgium, France, Luxembourg, Germany, the Netherlands and Switzerland).

4.1.3 Technologies for which significant decisions have been taken

4.1.3.1 Significant deployment decisions have been made in relation to implementation of VDL Mode 2 (VDL2), 1090 Extended Squitter (1090 ES) and Mode S Enhanced Surveillance (Mode S EHS).

4.1.3.2 VDL2 has been selected by some airlines, initially to support ACARS over AVLC (AOA) but also to support ATS Services using the Aeronautical Telecommunications network (ATN).

4.1.3.3 Both ARINC and SITA have significant programmes to deploy VDL2 ground stations. VDL2 is currently used to support a number of operational applications including ATIS in the United States. The FAA and Eurocontrol have selected VDL2 as the communications bearer for initial deployment of CPDLC. IATA supports these decisions.

4.1.3.4 Both the FAA[5] and JAFTI[6] have recently announced decisions to deploy 1090 ES as the initial bearer for air-air and air-ground broadcast services. In the US, Universal Access Transponder (UAT) will also be deployed to support General Aviation. A draft announcement from IATA, AEA and Eurocontrol indicates that 1090 ES has been selected as an initial ADS-B datalink in Europe[7]. The statement suggests that there is a potential requirement for a second link at a later date, and that work should continue on VDL4 to see if it is able to meet the future requirements.

4.1.3.5 In addition, the UK, France and Germany have announced an intention to mandate Mode S Enhanced Surveillance in 2005.

4.1.3.6 In response to the Mode S Elementary Surveillance mandate, and the expected Enhanced Surveillance mandate, Airbus and Boeing are certifying Mode S transponders with Elementary Surveillance, Enhanced Surveillance, and 1090 Extended Squitter ADS-B Out functions, along with the requisite aircraft installation wiring. Initial deliveries and service bulletins for in-service aircraft will start in the first quarter of 2003, in support of fleetwide compliance by 2005.

4.1.2 CANSO recommended that ANSP with requirements for point-to-point datalink and ADS_B adopt VDL2 and 1090 ES for use during the period 2003-2012 [262.]

4.1.4 Emerging technologies

4.1.4.1 Emerging technologies are those which have yet to enter operational service but for which significant standardisation, development and trials work has been carried out:

- VDL Mode 3 (VDL3);
- VDL Mode 4 (VDL4);
- Universal Access Transponder (UAT);
- Gatelink.

4.1.2 It should be noted however that decisions to implement each of these technologies have also been made:

- VDL3 is being deployed by the FAA to support voice communications in 2009 and data communications by 2012.
- VDL4: Sweden [271] and Russia [272] have announced plans to implement VDL4 for ADS-B. Comm4 Solutions are proposing a VDL4 network to support AOC applications [273].
- UAT: UAT has been selected by the FAA to support ADS-B applications for General Aviation community.

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[5] FAA Press Release APA 27-02, 1st July 2002. (See: http://www.faa.gov/asd/ads-b/press.htm)

[6] JURG ADS-B Fast Track Initiative

[7] European ADS-B Data Link Recommendation, December 2002

- Gatelink: BA, FedEx, Swissair and CONDOR have all supported operational trials of Gatelink.

4.1.4.1 In addition to these technologies, Mode S Data Link has also been standardised by ICAO. As no stakeholder has plans to implement Mode S Data Link it was not considered during the study.

4.1.5 Future technology

4.1.5.1 Future technologies are those for which there are emerging development plans but for which standardisation and demonstration is immature:

- Next Generation Satellite Service (NGSS);
- Satellite Data Link Service (SDLS);
- 3G/UMTS (CDMA Wideband);
- Boeing Connexion (Boeing CS).

4.1.5.2 Of these systems, 3G is considered to be a terrestrial system operating outside of the existing VHF allocation. The other systems are satellite based.

4.1.5.3 NGSS is used to refer to the LEO/MEO systems such as Iridium and Globalstar whose primary purpose was mass communications market but which initially offered aviation service. ICAO is currently considering none of these systems.

4.1.5.4 Boeing CS is a proprietary satcom system operating in Ka-band and is not intended for ATS.

4.1.5.5 SDLS is a long term ESA research programme aim at demonstrating improvements to the current AMSS. During the course of this study Eurocontrol have commenced work on NexSat which is a proposed L-band satcom solution which includes elements of the SDLS programme.

4.1.5.6 Other companies have shown interest in providing new aeronautical mobile satellite communications systems both in the existing L-band allocation and at other frequencies such as Ka- and Ku-band which do not have an aeronautical allocations. Given the embryonic nature of these systems they have not been discussed in detail.

4.1.6 Summary of technologies

4.1.1 Table 4-1 summarises the services supported by technologies considered during the technology assessment.

4.1.2 The characteristics listed represent the current understanding of the selected technologies. It is recognised that some technologies could be engineered to provide additional services, for example UAT could provide point-to-point services and the satellite systems could provide broadcast functionality.

Group	Technology	Air-Ground Datalink	Air-Air Datalink	Air-Air Broadcast	Uplink Broadcast	Downlink Broadcast
Baseline Technologies	AVPAC	✓				
	HFDL	✓				
	AMSS	✓				
Significant Decisions	VDL2	✓				
	1090 ES			✓	✓	✓
	Mode S EHS				✓	✓
Emerging Technologies	VDL3	✓				
	VDL4	✓	✓	✓	✓	✓
	UAT			✓	✓	✓
	Gatelink	Airport Only				
Future Technologies	NGSS	✓				
	SDLS	✓			✓	
	3G/UMTS	✓	✓	✓	✓	✓
	Boeing CS	✓				

Table 4-1: Summary data link technology characteristics

4.2 Assessment of point-to-point technologies

4.2.1 The following table summarises the key points made about each point-to-point technology during the assessment.

Technology	Points of Interest / Role in Datalink Roadmap
A.1.1 HFDL	▪ The existing HFDL is the only current system capable of covering polar routes. ▪ HFDL is hindered by very low data rates, but does support basic FANS1/A type applications and ACARS (ARINC). ▪ HFDL is retained in the roadmap for current use; but with long term replacement by future satcom possible.

Technology	Points of Interest / Role in Datalink Roadmap
AMSS	▪ AMSS is an existing system capable of providing narrow band data (throughput is approximately equal to VHF but transfer delay is much longer). ▪ Currently AMSS is used to support FANS1/A but also includes an ATN sub-network. ▪ AMSS is fitted to 2000+ mainly long haul aircraft. ▪ AMSS is hindered by high cost for avionics and communications charges. The price per kilobit could be lower if the system was used more. ▪ Retained for current use; replacement by future satcom is likely. Consideration of ATS use for Inmarsat-4 and Inmarsat-5 services is urgently required.
VDL2	▪ Significant deployment plans for VDL2/AOA ▪ The study estimated the effective data rate for VDL2 to be of order 3000 bps for en-route airspace (see technology assessment document P167D2020 Annex F for a discussion of this data rate). This figure was disputed during the public consultation. Eurocontrol is carrying out simulations to determine the actual rate. ▪ VDL2/ATN is planned to be the first continental ATC datalink. It will require several frequencies. ▪ As for other VDLs, VDL2 may not support long term datalink requirements because of the lack of spectrum availability. ▪ VDL2/ATN does not support long term goal of tactical datalinks (Eurocontrol’s view is that it is not able to support step 4 and beyond because of quality of service limitations). ▪ Retained for use as VDL2/AOA and ATC.
VDL3	▪ Significant support in US where VDL3 is expected to be the next generation technology for both ATS voice and data. AOC data would remain on VDL2 ▪ Subect to meeting NARC Criteria, VDL3 is expected to be initially deployed to provide digitised voice for high altitude en-route airspace in the 2009 timeframe. 8.33 kHz voice is the fall-back solution. ▪ The FAA does not expect to introduced VDL3 for data until around 2012 ▪ No support in Europe where 8.33 kHz voice is being implemented to redress shortage of voice channels; Europe does not have a long term strategy for voice. ▪ The combined voice and data makes VDL3 an attractive option for future deployment in the US; particularly as an ANSP replacing it’s voice infrastructure will effectively be deploying a datalink infrastructure. ▪ As for other VDLs, VDL3 may not support long term datalink requirements because of the lack of spectrum availability. ▪ VDL3/ATN protocols support deterministic quality of service and priority management and hence support the ICAO requirements for a tactical datalink, provided sufficient channels can be made available. ▪ If deployed in Europe, VDL3 would have to be deployed as a wide area data-link (3T-mode), but will require several frequencies.

Technology	Points of Interest / Role in Datalink Roadmap
VDL4	▪ VDL4 has only just been standardised for point-to-point communications, the DLS protocols were accepted by AMCP/8 as validated subject to flight trials. ▪ Maturity of avionics and ground stations is supported by the maturity of products for broadcast services. ▪ Integration of VDL4 onto a airframe already supporting VHF voice and VDL2 is still an issue. ▪ The effective data rate for VDL4 is 12 - 14 kbs (see technology assessment document P167D2020 Annex J for a discussion of this data rate), but it will require several frequencies. ▪ As for other VDLs, VDL4 may not support long term datalink requirements because of the lack of spectrum availability. ▪ VDL4/ATN protocols support deterministic quality of service and priority management and hence support the ICAO requirements for a tactical datalink, provided sufficient channels can be made available ▪ VDL4 is suited to the provision of an AOC communications for Regional and General Aviation operators who have not yet invested in ACARS, provided that a ground network is put into service. This is because fleet management applications are a natural consequence of the exchange of position in the system messages.
Gatelink	▪ A number of technologies have been proposed over the years for providing very high bandwidth communications for parked aircraft. The majority of the communications does not relate to ATC, although some clearances, including advanced slot management applications could be supported. ▪ Gatelink is an important enabler of Collaborative Decision Making (CDM). ▪ A European decision for a particular technology could support lower prices in the long term.
NGSS	▪ A number of potential NGSS, including Iridium, ICO and Globalstar, have been proposed over the years. These systems have their roots in mass personal communications. Only Iridium is still hopeful of providing an aeronautical service and is currently used for voice services by General Aviation in the US. ▪ The continued operational and financial difficulties of NGSS operators (due to the failure of their core non-aviation market) make them unattractive for commercial aviation. ▪ Current systems (ICO, Iridium and Globalstar) are not retained for inclusion in the roadmap. ▪ Future NGSS could be an important part of the aeronautical communications infrastructure.
SDLS	▪ SDLS is a research project sponsored by ESA ▪ Eurocontrol are developing a program called NexSat which reuses certain aspects of the SDLS programme. ▪ The design brief is to replicate VHF communications (voice and data) using a geo-stationary satellite. ▪ In its first guise, it would reuse existing Inmarsat infrastructure but use CDMA to improve services.
Boeing CS	▪ Broadband system capable of live TV to aircraft but has not been proposed for safety services. ▪ Not retained for inclusion in the roadmap

Technology	Points of Interest / Role in Datalink Roadmap
Broadband including 3G	▪ The aeronautical application of broadband technology including 3G is being researched by Eurocontrol, and the potential to offer significant advantages over VHF communications. ▪ Retained for use in Step 3. Significant research should be conducted into the best way of using 3G for aviation. This research should include security concerns of the use of a single channel to support all aircraft communications needs.

Table 4-2: Summary of Point-to-point technologies

4.2.1.1 Integration of multiple VHF radios on an airframe is a complicated issue which was discussed as the second stakeholder workshop. The workshop agreed that further work was required to clarify the issue and that consideration of the analogue voice radios was also required[8].

4.2.1.2 At this stage the debate is unresolved. Further work is required to clarify the issue. At the workshop Airbus stated that they had stopped work on VDL4 until this issue is resolved.

4.3 Assessment of broadcast technologies

4.3.1.1 The key results of the technology assessment for broadcast media are summarised below.

Technology	Points of Interest / Role in Datalink Roadmap
1090 ES	▪ Most mature of the proposed technologies with the earliest potential implementation date and possible widespread use by 2006. ▪ In support of the Mode S mandate, large airliners are being equipped with updated Mode S transponders from 2003, with fleet wide retrofit in 2005. These transponders also perform Mode S Enhanced Surveillance and 1090 ES functions. ▪ The air-air range of 1090 ES make it suitable for TMA applications but unsuitable for long-range applications. ▪ Implementation of 1090 ES would benefit from, and may even require, a concerted rationalisation of the SSR ground infrastructure. ▪ 1090ES does not support long term goal of broadcast datalinks. (Eurocontrol’s view is that it is not able to support step 5a because of increased traffic density). ▪ An ‘ADS-out’ solution is the cheapest way to get limited ADS-B capability. The TCAS functionality can be used to display proximate traffic based on 1090 ES returns. However, the usefulness of this display is low and a full CDTI or similar display will be needed for most air-air applications, as for VDL4 or UAT.

[8] For a fuller discussion of the issue see Technical Assessment (P167D2020) and Phase 2 Public Consultation (P167D016)

Technology	Points of Interest / Role in Datalink Roadmap
VDL4	▪ VDL4 is the most flexible of the proposed systems providing variable reporting rates and a wide range of intent data. ▪ VDL4 is able to provide other services such as ATN communications (recently standardised) and air-air point-to-point communications (it is the only link with an air-air data link). ▪ VDL4 has the best airport surface performance due to lower frequency of operation (it suffers fewer shielding problems). ▪ Airborne VHF interference issues are still being addressed by Airbus through the NUP programme. DSB-AM voice may be adversely affected by the operation of VDL4 on the same airframe. ▪ Deployment of VDL4 will require a concerted effort to free sufficient bandwidth in the congested VHF bands. The aviation position for agenda item 1.28 at the World Radio Conference in June 2003 (WRC-2003) deals with allocation of navigation and surveillance services supported by data links in the band 108-118 MHz and it is expected that the WRC-2003 will decide in accordance with the aviation position. Subsequently there will be no regulatory impediments against applying VDL Mode 4 as a data link supporting CNS applications. ▪ Work on a channel management plan, including identification of the number of VHF channels required, is critical and urgently required. ▪ Subject to resolution of airborne co-site interference issues, frequency availability and channel management plan VDL4 could be in use by 2006.
UAT	▪ UAT has been selected by the FAA to support ADS-B on general aviation aircraft. ▪ Simulations show that UAT has the best range/capacity performance of the proposed systems with sufficient capacity for all applications including FIS-B and TIS-B. ▪ UAT does not support the requirements for long-range applications or transmission of all the required intent parameters. ▪ UAT does not support an air-air point-to-point datalink. ▪ UAT requires SARPs standardisation work which can be a very slow process. To avoid significant delays, SARPs standards should have minimum deviation from the existing MOPS published by RTCA. ▪ There is a serious concern about the European availability of a suitable frequency for UAT before 2006 and even well after this date. This is due to the additional 180-200 DMEs required in Europe to support the proposed RNP RNAV mandate. (See section 7.10.2 for a further discussion of the issue). ▪ UAT could not be considered for operational use in Europe before 2006, and it may be longer since it depends on several factors being resolved quickly: SARPs completion, frequency availability and equipment availability.

Table 4-3: Summary of broadcast technologies

4.4 Scenario Assessment

4.4.1 A multi-criteria analysis of potential technology scenarios was conducted in order to select the most appropriate technologies[9]. Each scenario represented a technology selection for each of the five steps in the roadmap.

4.4.2 The following table is a reminder of the technology requirements for each step and identifies the potential technologies.

Step	Description	Technology Requirements	Candidates
1	Early a/g ATM applications.	This step requires the deployment of an initial air-ground datalink	VDL2 VDL4 AMSS[10]
2	ATM applications related to downlink of air-derived data.	Whilst this step could be achieved by the use of additional datalink applications, the lack of VHF frequencies has led to the recommendation that a downlink broadcast media is deployed[11].	Mode S EHS 1090 ES VDL4
3	Introduction of spacing.	This step requirements the deployment of ADS-B within the aircraft including processing and display capabilities. It could be supported by the use of TIS-B.	1090 ES VDL4
4	Extension of a/g ATM applications.	This step involves additional use of the air-ground datalink, it could involve the deployment of a new technology or just additional frequencies.	VDL2 VDL3 VDL4
5a	Introduction of separation and self-separation.	Dual-link ADS-B solution including a point-to-point air-air capability.	1090 ES and VDL4 1090 ES and E-UAT VDL4 and UAT
5b	Introduction of conflict free trajectory negotiation	Enhanced air-ground datalink supporting	3G SDLS

Table 4-4: Technology steps in the datalink roadmap

[9] Please refer to Section 7 of the Technology Assessment Document (P167D2020) for full details of the multi-criteria analysis.

[10] AMSS is included in the roadmap for APP14a (Oceanic ATC) but is not considered in the main analysis which considered core-Europe requirements.

[11] The rationale for this recommendation is presented in P167D2020 Section 5.

4.4.3 The potential scenarios considered are defined in Table 4-5.

Step / Scenario	1	2	3	4	5a	5b
A	VDL2	Mode S EHS (1090 ES)	1090 ES	None	VDL4	Newcom[12]
B	VDL2	Mode S EHS (1090 ES)	1090 ES	None	UAT	Newcom
C	VDL2	Mode S EHS (1090 ES)	1090 ES	None	None	Newcom
D	VDL4	VDL4	VDL4	None	UAT	Newcom
E	VDL2 or VDL4	Mode S EHS (1090 ES) or VDL4	1090 ES or VDL4	None	VDL4 or 1090 ES	Newcom
F	VDL2 or VDL4	Mode S EHS (1090 ES) or VDL4	1090 ES or VDL4	None	UAT	Newcom
G	VDL2	Mode S EHS (1090 ES)	1090 ES	VDL4	VDL4	Newcom
H	VDL2	Mode S EHS (1090 ES)	1090 ES	VDL3	UAT	Newcom

Table 4-5: Potential Scenarios

4.4.4 These scenarios were selected to include those considered by the consortium on the evidence gathered during the technology assessment to offer the most likely, the lowest cost, and most beneficial roadmaps. Limited alternatives have also been included for comparison.

4.4.5 The multi-criteria analysis included consideration of:

- Ability to deliver the ATM application roadmap;
- Overall Cost;
- Frequency Availability;
- Global interoperability;
- Support for voice;
- Support for non-ATC communications.

[12] Newcom is used to refer to a future broadband system outside the VHF spectrum and would include both terrestrial and satellite systems..

4.4.6 Table 4-6 summarises the scoring for the potential scenarios[13].

	Weight	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Benefits	6	4	4	3	3	5	5	5	5
Costs	5	3	4	5	5	5	4	2	2
Frequency Availability	4	3	2	4	2	3	2	2	1
Global Interoperability	2	3	3	3	1	3	3	3	4
Voice Communications	2	1	1	1	1	1	1	1	1
Non-ATC Data Comms	1	2	2	2	3	4	4	4	4
Total (Weighted)	100	**61**	**62**	**69**	**58**	**79**	**70**	**60**	**58**

Table 4-6: Scenario scoring summary

4.4.7 The following notes assist in the interpretation of Table 4-6:

- 3 scenarios (C, D and E) represent the lowest cost. The scoring system assigned a score of 5 to the scenarios which came within 10% of the lowest cost solution. In the analysis, there was little cost differentiation between a route based on VDL2/Mode S EHS/1090 and one based on VDL4. The VDL4 route was marginally lower cost. The combination of scenarios C and D in steps 1, 2 and 3 to produce scenario E add costs associated with duplication of ground infrastructure. However, the increase in cost remains within 10% of the lower cost option – hence this scenario also scores 5. Scenarios G and H score poorly on costs because they involve an extra (or earlier) equipage stage for step 4.
- For benefits, scenarios C and D both scored poorly: C because it is unable to meet the requirements in steps 4 and 5a, D, based on VDL4, because it results in a delay to start of the roadmap.
- For frequency availability, VDL2 only solutions have been given a higher score on the basis that an initial spectrum allocation has already been made. Note that solutions requiring two VDL links score poorly.
- For global interoperability, VDL4 solutions score poorly since there is no acceptance of VDL4 within the US. Conversely, solutions based on VDL3 and UAT score more highly on the basis that these correspond to current plans within the US.
- For voice communications, all solutions score 1 since it is assumed that, over the timescale of the roadmap, Europe will follow an 8.33kHz path.
- Non-ATC communication scoring is assigned on the basis of the data efficiency of the proposed solutions.

[13] The scores presented have not been updated following public consultation and the comments received on scores were not consistent.

4.5 Scenario Selection

4.5.1 Recent Decisions

4.5.1.1 Whilst the project has been in progress, a number of significant decisions/recommendations have been made by the community including:

- a decision in the US to adopt 1090 ES as the first ADS-B link;
- recommendations by JURG to follow the US approach for the first ADS-B link;
- a preliminary Eurocontrol decision to support 1090 ES as first link with a recommendation to investigate the need for and use of VDL4 as a second link, subject to proving of VDL4 performance;
- expectation of a mandate for Mode S enhanced surveillance in at least three core European states;
- CANSO support for VDL2 and 1090 ES [263].

4.5.1.2 For these reasons the first three steps have been determined by the industry as:

- Step 1: VDL2
- Step 2: Mode S EHS
- Step 3: 1090 ES

4.5.1.3 Scenario E is consistent with these steps with an additional route based on VDL4 for airspace users who have not previously invested in ACARS.

5 Technology roadmap

5.1 Introduction

5.1.1 The study assessed all candidate technologies in terms of performance, cost and maturity, and considered explicitly a number of implementation scenarios in which combinations of technologies were used to support the 5 steps in the ATM application roadmap.

5.1.2 It was concluded that the data link technologies necessary to deliver the ATM application roadmap up to and including step 4 are already available or close to being available and, assuming implementation constraints can be addressed, could be implemented in time to meet demand. Furthermore, a number of candidate data link technologies were identified which may be alternatives to meet the requirements of step 5.

5.1.3 The study analysed a number of scenarios combining the data link technologies [14]. All of the scenarios considered provide benefit [15] but costs may vary from one scenario to the other .It should be noted that important issues need to be solved in order to deliver the benefits.

5.1.4 Factors which support the implementation of certain data link technologies include:

- The availability and capability of technologies[16].
- The availability of standards for airborne and ground equipment.
- Decisions and recommendations made by the community in support of the implementation of VHF Data Link Mode 2 (VDL2) for airline operational communication (AOC) and a first set of ATM applications grouped under the name of LINK 2000+ and 1090 MHz Extended Squitter (1090 ES) for a first set of ADS/B applications [17].
- Consensus from at least France, the UK and Germany, their relevant ANSPs and some airlines towards implementation of Enhanced Surveillance based on Mode S (Mode S ES) in core Europe, building on the current mandate for Mode S Elementary Surveillance[18].

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[14] Details of the scenarios considered are contained in P167D2020 Section 7. The high level cost benefit assessment is described in P167D2010 Section 6.

[15] Net benefit was typically of order €10 Billion using a discount factor of 8%.

[16] The technology assessment document (P167D2020) contains an annex for each of the considered technologies including a summary of the evidence presented against which maturity was assessed.

[17] The decisions and recommendations that the study team were made aware of are summarised in paragraph 4.5.1.1.

[18] The 'three states plan' (signed in 2002) identifies the 31st March 2005 as the mandate date. Draft mandates have been issued for 'consultation' and are going through the Notification of the Proposed Rule Making (NPRM) process at the moment. Notification of support for VDL2 and Mode S EHS implementation by DFS and NATS was obtained during the second public consultation phase. – see P167D016 Section 6 and Annex A comments 515 to 518.

- Investment by ARINC/SITA in VDL2 ground networks for AOC applications[19].
- Investment by Airbus in solutions to support a data link technology route based on VDL2, Mode S EHS and 1090 ES[20].
- Emerging plans for a VHF digital link Mode 4 (VDL4) AOC network[21].
- Investments made by EU and project partners in EU sponsored test and trials projects of VDL4 for ADS-B ATM applications[22].
- Plans for implementation of VDL4 based ATS networks in Sweden and Russia[23].

5.1.5 The barriers to reaching a decision on the implementation of data link technology include:

- **Technical issues:** A number of technical issues with the proposed links were raised by the study and need to be resolved or alternative solutions must be pursued. The key issues [24] were:
  - Performance issues and spectrum consequences with each link, including uncertainty and lack of simulation data on the effective data rates of VDL2, VHF digital link Mode 3 (VDL3) and VDL4.
  - Co-site issues including whether interference between one VDL radio and another VDL or current voice radios could be controlled or eliminated by technical means. A particular issue may arise when radios are transmitting repetitively.
  - The need to understand how a transition to VDL3 could be made.
  - The need to derive frequency planning criteria for VDL3 and VDL4 and to investigate frequency availability in Europe for UAT.
  - Spectrum shortage in the VHF Communication band driven by the saturation of the spectrum by voice channels, exacerbated by an inefficient use of existing spectrum.

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[19] Current implementation plans for Mode 2 presented to the study team by ARINC and SITA are summarised in P1672020 Section F.5.

[20] Details of the equipage steps and timescales envisaged by Airbus are contained in paragraph 6.3.12.

[21] Plans for a VDL4 AOC network were announced during phase 2 of the study – see P167D016 Section 6 Annex A comment 286.

[22] A summary of trials activity involving VDL4 is contained in P167D2020 Section J.

[23] VDL4 implementation plans are described in P167D2020 Section J.3.3.

[24] The issues are summarised in Sections 4.2 and 4.3. More detail can be found as follows in the study documentation:

- performance and spectrum issues P167D2020 Section 5.2.1 (point to point services) and P167D2020 Section 6.2.1 (broadcast services);
- co-site issues P167D2020 Section 5.2.3.

- Incomplete demonstration of data link technical and operational performance during all phases of flight.
- Incomplete assessments of integrity and availability requirements for ADS-B.

- **No agreed solution for all users:** No single solution appears to be suitable for, or is supported by, all users. For steps 1 to 3 the view of the community is split[25]:
  - ANSPs operating in core Europe, IATA, and Airbus see a route starting from VDL2, Mode S EHS and 1090 ES as the most pragmatic way forward with SITA and ARINC supporting VDL2 for AOC and ATM applications as described under the programme LINK 2000+.
  - The General Aviation community, Swedish and Russian ANSPs, and a low cost carrier (EasyJet) see a solution based on VDL4 as the cheapest way forward for a combined set of applications.
- **High investment costs:** The required investment is very high for any alternative considered, and hence the Community must act to ensure that maximum short, medium and long term benefits are achieved in a timely manner and that the highest possible return on investment is obtained. This means that decisions made at any time must be supported by strong business cases and appropriate for the longest possible time frame.

5.2 Possible strategies for data link implementation

5.2.1 There is full consensus in the community that implementation of data link technology is essential to meet future needs and that it is urgent that the community starts as soon as possible with implementation programmes. However, there is no consensus on how to move forward.

Options for Steps 1, 2 and 3

5.2.2 The deployment of VDL2, Mode S EHS and 1090 ES to support the requirements of Steps 1, 2 and 3 in the ATM Application Roadmap is based on:

- The possibility to expeditiously deploy VDL2 taking advantage of the maturity of the technology and of a business case starting with AOC services over VDL2 based on saturation of the ACARS system and the possibility to expand the utilisation of VDL2 to non time critical ATM applications as described in LINK 2000+ and in Step 1 of the Application Assessment. There is consensus among some actors as to the implementation of such ATC services using ground infrastructure at the core-European area centres.
- Widespread equipage with Mode S EHS through a mandate in some core states and their current plans for establishment of a network of Mode S radar stations;
- The availability of 1090 ES ADS-B “out” resulting from equipage to support Mode S EHS, followed by a subsequent upgrade to support ADS-B “in”.

[25] The best illustration of the division in the Community can be found from the comments received during the second public consultation P167D016.

- It would result in a common decision across the Atlantic for 1090 ES as an interoperable link.
- .

During the public consultation process, this route was supported by Airbus, IATA, DFS, NATS, and Eurocontrol[26].

5.2.3 There is also support for alternative solutions in Steps 1, 2 and 3 based on VDL4 for:

- regional AT operations and General Aviation;
- a low cost carrier - EasyJet;
- non-core European regions including Russia, Mongolia and Sweden.

5.2.4 The driver for this scenario relies on:

- exploiting the ability of VDL4 to provide broadcast and point-to-point services as a “generic” enabler for all considered applications;
- achieving a lower cost route for some operators and service providers;
- progressing a system which might prove essential in step 4 and 5.
- making more efficient use of available spectrum

During the public consultation process, this route was supported by Marconi Selenia Communications, Com4 solutions, CNS Systems, EasyJet, IAOPA and LFV[27].

5.2.5 It should be noted however that both scenarios are not exclusive, e.g. the GA would not be forced to equip with VDL2 assuming only about 75% rate of equipage is required for step 1 applications.

Options for Step 4

5.2.6 Eurocontrol believes that for Step 4, VDL2 will not provide the QoS required by the related ATM applications. This view is not shared by ARINC and SITA and this requires further exploration and in particular as to the ability and capability of the technology supported by SITA/ARINC and their commitment to delivering the required QoS[28].

5.2.7 The analysis conducted within the study also concluded that the number of VHF channels needed to support the operation of any VDL system, and, in particular, VDL2, during Step 4 may be too high to be accommodated within the currently planned allocation of VHF spectrum. This view, at least in regards to VDL2, was criticised during the public consultation process for two reasons:

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[26] Support for VDL2/Mode S EHS/1090 ES route - see comments by Airbus, DFS, NATS, Eurocontrol, SITA and ARINC in P167D016.

[27] Support for VDL4 route – see comments by Marconi Selenia Communications, Com4 solutions, CNS Systems, EasyJet, IAOPA and LFV in P167D016.

[28] Eurocontrol and SITA views on limitations of VDL2 in step 4: see P167D016 Annex comments 47 and 164

- There was no agreement on the quoted figures for the performance of VDL2.
- The timescales for equipage of VDL2, provided by stakeholders, lag behind the ATM application roadmap timescales by 4 to 6 years – this means that the predicted performance shortfall may not occur until much later but that the benefits expected from the ATM application would be significantly delayed[29]. However, this reason cannot be accepted, based on the necessity to meet demand.

5.2.8 IATA and AIRBUS are of the opinion that because the VHF band is reaching its limits in terms of spectrum there is a need to explore solutions outside the VHF band.

5.2.9 The community therefore needs to determine whether it wishes to support part or all of step 4, based on actual benefits versus the cost and in particular the shortage of spectrum. and whether VDL2 is a realistic candidate. Assuming that VDL2 is not a candidate for this step, or is a partial candidate only, the study has identified the following options for further consideration:

- Delay implementation of part or all of these ATM applications, and hence delay the benefits, until a new technology operating outside the VHF spectrum has been developed.
- Implement a different VDL solution which provides a greater data throughput than VDL2. Note that both VHF Data Link Mode 3 (VDL3) and VDL4 are candidates for this step. Currently Eurocontrol expects that VDL4 will be the most likely link for Europe. The disadvantages include the additional cost of the second link and the need to solve some remaining technical problems, not least the integration of existing voice/ACARS/VDL2 and new VDL3 or 4 on the same airframe. A further objection to both VDL3 and VDL4 is that they would compete with the spectrum allocation for VDL2, once approved and in place, although both VDL3 and VDL4 potentially provide higher data rates on a channel with the potential for more efficient use of spectrum.
- Accelerate the development of data link technology for Step 5b and use it to support step 4. It is expected that this would be based on broadband technology. The advantage of this solution, if achievable, is that the costs associated with an interim step to a second VDL link may be avoided. The disadvantage is that alternatives, if available, will take time to develop.

Candidate technologies for Step 5

5.2.10 The study has concluded that:

- The volume of aircraft-ground data exchanges, the increasing criticality of these exchanges, and the shortage of VHF spectrum may require the introduction of an alternative aircraft-ground data link technology to support Step 5b (and probably Step 4).
- There are capacity and quality of service issues with 1090 ES as an ADS-B solution which will necessitate supplementation or replacement of this link in Step 5a.

[29] Discussion on performance of VDL2 and timescales contained in P167D2020 Sections 5.2.1, 6.2.1 and F.

- ATM applications in Step 5a may require (subject to further analysis) direct air-to-air communication.

5.2.11 Therefore the later steps in the roadmap will require a common set of technologies to be deployed across the fleet and the ANSPs of the core area therefore, in the short term, there is an urgent action to determine what solution will be most suitable.

5.2.12 The study concluded that the most likely solutions to consider further are a dual 1090 ES/VDL4 data link or a dual 1090 ES/UAT data link for broadcast applications, with a solution for point-to-point communication based on broadband technologies. The community urgently needs to commit itself to the research and development of an appropriate and globally agreed solution.

5.2.13 Further detail of the two proposed routes is provided below.

5.3 Overview of VDL2/Mode S/1090ES Roadmap

5.3.1 Step 1: early a/g ATM applications

5.3.1.1 The data link technology support for high-and-medium-traffic-density continental regions in step 1 will be based on VDL2:

- the required airborne equipment is a VDL2 transceiver and CMU or ATSU;
- the required ground equipment is a VDL2 ground station network and appropriate centre equipment modifications.

5.3.1.2 For remote/oceanic regions, the equipage will be based on AMSS satcom using FANS1/A systems. Subject to safety studies, FANS1/A aircraft will be accommodated when departing/arriving in VDL2 airspace, or will be updated to VDL2/AOA[30].

5.3.1.3 Rationale:

- Most mature of the proposed technologies with the potential to be operational by 2004.
- Strong support in Europe to use VDL2 as the prime enabler for ATN compliant data link due to the AOC usage of VDL2 making the investment more productive.
- VDL2 can meet the early requirements of ATM applications in step 1.

5.3.1.4 Issues:

- The proposed Eurocontrol frequency plan for the EUR regions allows for four VDL2 channels including AOC. It is uncertain how many channels will be required to provide an adequate level of performance as traffic grows and new ATM applications are added. This issue will become particularly important when an extension of a/g services is provided in step 4 (see section).

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[30] The reverse will also be true, as CPDLC/ATN equipage increases in future for domestic applications, pressures will develop to be able to "accommodate" CPDLC/ATN technology in oceanic & remote areas.

- VDL 2 simulations and simulations with point-to-point applications will be needed to confirm the real ability of the media to support simultaneous point-to-point communications by the forecast population of aircraft and to provide information to support frequency planning for VDL2.

5.3.2 Step 2: ATM applications related to downlink of air-derived data

5.3.2.1 The data link technology support for step 2 will be Mode S enhanced surveillance with 1090 ES used as a gap filler and potentially as sole means in certain airspace:

- the required airborne equipment is a Mode S transponder that supports both Mode S enhanced surveillance and 1090 ES supporting ADS-B out only;
- the required ground equipment is a mixture of Mode S enhanced surveillance ground stations and 1090 ES receivers.

5.3.2.2 Rationale:

- It is being provided as an upgrade to Mode S elementary which is already mandated in core Europe for 2003;
- a Mandate for Mode S enhanced surveillance is being considered in some countries;
- standards and equipment for provision of ADD via Mode S enhanced surveillance are mature.

5.3.2.3 Issues:

- Further upgrade to 1090 ES may lead to savings in terms of Mode S ground station infrastructure by reducing the need for Mode S enhanced surveillance ground stations in favour of 1090 ES ground stations.
- Trials are required to demonstrate the feasibility of ADS-B as an alternative source of ADD.

5.3.3 Step 3: introduction of spacing

5.3.3.1 The data link technology support for step 3 will be based on 1090 ES ADS-B in:

- the required airborne equipment is a Mode S transponder as per Step 2 plus a 1090 ES receiver (potentially TCAS box), CDTI and an ASAS processor;
- the required ground equipment is a 1090 ES TIS-B network for gap filling.

5.3.3.2 Rationale:

- no additional transponder will be required over the Mode S mandate(although it is noted that aviation costs are dominated by CDTI/ASAS processor and other HMI costs).
- it can support early ATM applications;
- it is the most mature of the proposed technologies with the earliest potential implementation date and possible widespread use by 2006.

- 1090 ES is expected to be able to meet the early requirements although there is some doubt on range performance as traffic levels increase beyond 2010.
- provides interoperability with the solution being adopted in the US.

5.3.3.3 Issues:

- Simulation results indicate that 1090 ES will saturate in core Europe between 2010 and 2015.
- The air-air range limitations of 1090 ES make it suitable for core-area and TMA operations, but unsuitable for long-range applications.
- Implementation of 1090 ES would benefit from, and may even require, a concerted rationalisation of the SSR ground infrastructure.
- Further work on ground antenna siting criteria is required.
- The upgrade costs associated with this step are related to cockpit displays and ASAS processing requirements.
- The link is unproven in airport region for airborne applications;
- Work is required to determine how many antennas are required;
- Trials are required to demonstrate performance of 1090 ES in the European region.

5.3.4 Step 4: extension of a/g ATM applications

5.3.4.1 No consensus has been reached on the need to deploy an additional datalink to support step 4.

5.3.4.2 Calculations indicate that a high number of VDL2 channels are needed to support the required communications load during step 4. Results obtained within the study[31] calculations indicate that:

- 8 channels will be required to support ATS requirements during step 1 rising to 9 channels in 2010.
- A further 7 channels are required to support step 4 in 2010.

These requirements are in addition to guard bands and the channels necessary to support AOC.

5.3.4.3 These values are based on high equipage and application take-up. Slower equipage and low application usage would result in less channels being needed. Detailed simulation work is required to provide estimates of channel requirements.

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[31] Calculations performed within the study estimated the effect data rate of VDL Mode 2 to be 2,800 bps for en-route traffic, 3,454 bps for terminal traffic and 9734 bps for surface traffic. Stakeholder comments received indicate that the effective data rate for VDL2 is 10 times that of ACARS (300 bps) and 12-18000 bps for a single aircraft. These figures are consistent with the calculations performed. See P167D2020 Section 5 for further details.

5.3.4.4 It should be noted that the vast majority of aviations VHF spectrum allocation is consumed by the requirements for voice channels, and that despite the introduction and continued expansion of 8.33 kHz voice, that demands for additional voice channels can not always be met and that saturation will occur around 2010. To some extent, the effective data rate of the chosen VDL is of secondary importance to the voice issue.

5.3.4.5 Both VDL3 and VDL4 are able to provide greater effective data rates. In its 3T (Wide-area data only mode) configuration, VDL3 is able to provide an effective data rate of 12400 bps. The effective rate of VDL4 has been estimated as 14000 bps per channel (See P167D2020 Annex J for a discussion of this data rate).

5.3.4.6 Although it is likely that VDL3 and VDL4 can provide a more efficient use of the spectrum, it is difficult to escape the conclusion that, whatever route is taken for step 4, shortage of VHF channels will prevent the expansion of the services needed to support step 4[32].

5.3.4.7 The situation can be alleviated to a degree by making a focus of re-sectorisation within Europe the need to reduce the requirement for voice channels (ie actively move to larger sectors). It is however noted, that the traffic growth will require further airports, which will increase the need for VHF voice channels. Channel usage efficiency could also be promoted by re-assessing the manner in which channels are allocated. Finally, some channels could be saved by moving AOC voice channels to data.

5.3.4.8 Hence alternatives approaches may need to be considered. These would include:

- Adoption of VDL3 in wide area data only configuration;
- Adoption of VDL4
- Earlier introduction of the new technology needed for step 5.

5.3.4.9 Of these options, the preferable option from the point of view of cost is to make an early start on the new technology needed for step 5 since it avoids a further equipage step. However, considerable work needs to be carried out in order to develop and standardise such a technology.

5.3.4.10 If a new data link technology is deployed to support step 4 then either an upgrade of the VDL2 ground network or a new ground network would be required.

5.3.4.11 This step will also require enhancements to the CWP and FDP.

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[32] The importance of efficiently using the aviation frequency allocations was mentioned by several stakeholders during the consultation process. It is noted that the following recommendation was included Department of Trade and Industry review of Spectrum Management in the UK:

Recommendation 12.1: For spectrum reserved for on-board navigation and communications systems, the opportunity cost to individual users is, in most cases, effectively zero, since use of this spectrum is mandated internationally, and users are required to adopt specific technologies. But where UK-based users face some technology choice for their on-board systems, then the RA, working with the CAA and MCA, should apply differential licence fees to encourage moves to more spectrally efficient equipment, thus easing congestion over time.

5.3.5 Step 5a: introduction of separation, self-separation

5.3.5.1 Technology choice for Step 5a is driven by the answers to the following questions:

- *Is a complimentary broadcast datalink required to support 1090 ES in Core Europe?*

  The TLAT results [152] indicate that the range available from 1090 ES is very dependent upon interference levels and hence traffic density. The results suggest that whilst 1090 ES is able to support ADS-B at predicted traffic densities for 2010, it will not be able to do so for 2015 traffic levels.

- *Is a dual link solution required to support enhanced availability, integrity and continuity of service requirements for separation and self-separation applications?*

  In 1998, Project Emerald [14] concluded that a dual link solution would be required to support separation and self-separation applications. Whilst generally accepted at the time, and not seriously challenged since, the R&D required to prove this assertion has not been performed. It can not be said to be a definitive statement.

  However, the TLAT simulations [152] indicate that no single link is able to support all criteria; hence, a dual link solution is considered the safest approach.

- *Is an air-air point-to-point datalink needed to support self-separation applications?*

  It has been postulated that self-separation applications will require an air-air point-to-point datalink to support target identification and negotiation of passing manoeuvres the operational requirements for these applications have not been finalised and an definitive answer to this question is not yet possible.

5.3.5.2 Of the current technologies either VDL4 or UAT could be deployed to support 1090 ES:

- VDL4 has greater maturity, ability to support air-air point-to-point communications and support in Europe. However, further research is required to support airframe integration, channel management and capacity constraints.

- UAT is less mature but simulations demonstrate that it has a far higher capacity. It should be noted however, that a recent study [258] has suggested that the introduction of RNP RNAV in Europe will require an additional 180-200 DMEs. This will increase the current difficulty in obtaining a frequency for UAT in Europe.

5.3.5.3 At this stage, no clear decision can be made.

5.3.5.4 In the future, it is also likely that the data broadcast will evolve with greater integration of flight management computers and navigation sources. A more intent based form of free flight is attractive with information of where an aircraft intends to be at various times in the future being broadcast. Such a system could be supported by the advanced technologies considered in Step 5b.

5.3.6 Step 5b: conflict free trajectory negotiation

5.3.6.1 The introduction of conflict free trajectory negotiation is predicated on the transition to 4D RNAV and the deployment of an enhanced datalink capable of supporting the increased traffic volumes and tactical real-time nature of the data transfers. Hence, the key challenges for Step 5b are:

- To support time critical ATC messages;
- To support trajectory negotiation messages;
- To support continued voice operation;
- To support high bandwidth requirements for non-ATS applications.

5.3.6.2 The key question is: *Which future communications technologies should be deployed to support the long-term (2020+) requirements?*

5.3.6.3 A number of advanced media have been considered, namely:

- AMSS enhancements such as Swift64 and those enabled by Inmarsat-4 and Inmarsat-5
- SDLS
- NGSS
- 3G

5.3.6.4 Of these, a combination of terrestrial 3G and a satellite system based on CDMA is likely to offer the most beneficial combination. Research is urgently required to assess the feasibility of this solution.

5.3.6.5 It should be noted that new satellite technologies are likely to emerge in the interim. The use of regenerative digital payloads will enable far greater capacity than those envisaged for SDLS. Capacity could also be increased by the use of Ka-band or Ku-band frequencies. Such a solution would support a highly capable pipe to the aircraft which could be used for ATC, non-ATS applications, including passenger voice and internet access and ATS voice. Research is required to support the certification of such a system.

5.4 Alternative route based on VDL Mode 4

5.4.1 Introduction

5.4.1.1 During the study, there has also been a level of support by some operators for alternative solutions in steps 1, 2 and 3 based primarily on VDL4 and, in particular, for regional AT operations, GA and military[33]. The driver for this scenario relies on providing lower cost avionics for these operators, although further work is required to demonstrate that low cost solutions could be provided.

5.4.1.2 This route for equipage is strongly opposed by a large part of the community for reasons that include:

[33] Stakeholder comments to this effect were received from Easy Jet, Comm 4 Solutions, IAOPA. Eurocontrol indicated that they felt military users would not support VDL4 equipage on cost grounds,

- Requiring additional VHF spectrum that should be reserved for VDL2;
- Delaying the start of the roadmap
- Not compatible with current plans for large Air Transport aircraft equipage in the next 10 years.

5.4.2 The two roadmaps would converge at step 5.

5.4.2 Step 1: early a/g ATM applications

5.4.2.1 The data link technology support for step 1 for some operators will be based on VDL4:

- the required airborne equipment is a VDL4 aircraft/ground point to point package (note that later cost analysis assumes full package, including broadcast functions implemented at this step);
- the required ground equipment is a VDL4 a/g point to point network and connection to upgraded centre equipment.

5.4.2.2 Rationale:

- Plans have been announced for an AOC network based on VDL4 which would provide additional non-ATS benefits.
- ATS requirements can be met via use of this network
- VDL4 has potential to meet early requirements although simulations and trials need to be carried out;
- VDL4 is able to provide services such as ATN communications and air-air point-to-point communications (it is the only link with an air-air data link, which needs to be demonstrated).
- VDL4 is not expected to provide a more efficient use of the VHF spectrum than VDL2 - although detailed simulations are required to demonstrate this.

5.4.2.3 Issues:

- Simulations are required to establish the number of VHF channels required to provide performance;
- Resolution of issues concerning VDL integration within airframe (see Section 4)
- Deployment of VDL4 will require a concerted effort to free sufficient bandwidth in the congested VHF bands.
- Work on a channel management plan, including identification of the number of VHF channels required, is critical and urgently required. Note that there are currently no activities to provide a channel for VDL4 point to point.
- Subject to cost-effectiveness, frequency availability and channel management plan – which are serious constraints - VDL4 could be in widespread use by 2006. Note that this will delay benefits obtained from step 1 for operators choosing this route relative to route 1.

- VDL4 point-to-point simulation results will have to confirm the VDL4 ability to support ATM applications that are most capacity demanding. Simulation results will be needed to confirm this.

5.4.3 Step 2: ATM applications related to downlink of air-derived data

5.4.3.1 Operators following route 2 have a potential choice at step 2:

- Inexpensive upgrade of Mode S elementary surveillance to Mode S enhanced surveillance (ie the same as route 1) is expected to be mandatory in 3 core-area States, resulting in equipage of all airliners, except for those very few aircraft allocated to local service exclusively.;
- or using the VDL4 ADD capability:
  - the required airborne equipment would be upgrade of VDL4 equipage to provide connection to FMS;
  - the required ground equipment would be VDL4 stations integrated with the surveillance network..

5.4.3.2 Noting that the upgrade to Mode S enhanced surveillance is available at relatively low cost (see section 6.2) and noting the expectation of a Mode S enhanced surveillance mandate in some states, it is expected that almost all operators will choose the Mode S upgrade path in this step. The use of VDL4 for ADD is expected to be supported by some states. Sweden and Russia have both announced plans to implement ADS-B using VDL4.

5.4.3.3 The rationale and issues for Mode S upgrade was set out in section 5.3.2. The remainder of this section presents the rationale and issues for choosing a Mode 4 solution for this step.

5.4.3.4 Rationale:

- avionics costs reduced by avoidance of need to support Mode S enhanced surveillance ground and airborne infrastructure, but augmented considerably by having to install extra VDL4 equipment and antennas.

5.4.3.5 Issues:

- Use of VDL4 for ADD requires closer integration with the surveillance network, something which may not be provided by the network used for AOC/ATS in step 1. This raises institutional issues for data ownership and technical issues for introduction of data into surveillance network. It is possible that a separate VDL4 network would be required either sharing ground stations or implementing ground stations dedicated to the ADD applications required in this step and the support for spacing in Step 3.

5.4.4 Step 3: introduction of spacing

5.4.4.1 The data link technology support for some operators in step 3 will be based on VDL4 ADS-B:

- the required airborne equipment is an upgrade of the VDL4 equipage to provide a CDTI, other HMI equipment and ASAS processor;
- the required ground equipment is a VDL4 TIS-B network for gap filling.

5.4.4.2 Rationale:

- can support early applications and later long range applications
- VDL4 is the most flexible of the proposed systems providing variable reporting rates
- VDL4 has potentially the best airport surface performance due to lower frequency of operation (it suffers fewer shielding problems).
- VDL4 can meet requirements in the first 10 years (particularly since the parallel use of 1090 ES will reduce the load on the VDL4 channels.
- the performance of VDL4 is not limited in the longer term if sufficient spectrum can not reasonably be made available.

5.4.4.3 Issues:

- the supply of sufficient spectrum provides a significant barrier to the ability of VDL4 to support ATM applications in core areas
- link unproven in airport region
- not interoperable with ADS-B solutions currently proposed for adoption elsewhere in the world.

5.4.5 Step 4: extension of a/g ATM applications

5.4.5.1 The data link technology support for some operators for step 4 will be based on VDL4 as a development of the network introduced for step 2.

5.4.5.2 Note that although it is expected that VDL4 can provide a more efficient use of VHF channel than VDL2, it is still likely that a significant number of channels will be needed to support VDL4 during this step

5.4.5.3 Rationale:

- Advanced CPDLC builds on VDL4 capability introduced in step 2.

5.4.5.4 Issues:

- there is some doubt as to whether VDL4 can support step 4 ATM applications within a reasonable core-area channel allocation.

5.5 Conclusions

5.5.1 No consensus has emerged for the first three steps of the technology roadmap. An industrial view is that the first three steps should be:

- Step 1: VDL2
- Step 2: Mode S EHS
- Step 3: 1090 ES

5.5.2 However, support for the first three steps to be based on VDL4 was also received.

5.5.3 Nor has consensus has emerged for Steps 4 and 5a. Serious technical concerns exist over the capability of VDL2 and 1090 ES to support the requirements in the 2010 to 2015 timeframe.

5.5.4 Eurocontrol are currently investigating the applicability of VDL4 for both Steps 4 and 5a.

5.5.5 Consensus has emerged that Step 5b should be supported by a media not in the VHF band, and that this technology should be capable of supporting all the communication requirements.

5.5.6 The next generation systems supported for Step 5b are still largely on the drawing board. As they are based on COTS, standardisation is likely to be quicker for these technologies than for aviation specific technologies such as Mode S. However, significant risk still exists in the development of these technologies to meet the aviation specific requirements. It is likely that such a solution will not be available until 2015-2020.

5.5.7 It is therefore recommended that before reaching final decisions on the technology roadmap, the following actions are completed:

-
- In order to determine the need for additional technology in Step 4, detailed analysis, in particular large-scale simulations are conducted to support frequency requirements for VDL2.
- In order to determine the need for additional technology in Step 5, detailed analysis is continued on the performance of 1090 ES in dense traffic/high interference environments.
- Detailed studies are undertaken to resolve remaining technical issues surrounding VDL4, this should include determination of effective data rate using high-fidelity large scale simulations and work on onboard architectures
- The specification of DSB-AM radios should be re-visited to see if interference from VDL can be reduced.
- Frequency Planning Criteria are developed for VDL3 and VDL4.
- Research into the ‘Newcom’ is given a high priority including both terrestrial and satellite technologies.

5.5.8 European institutions continue to monitor and support US developments in VDL3 and UAT in case these technologies are able to provide a better solution than VDL4.

A detailed technical and cost benefit assessment is conducted to support. The study should consider all options be conducted in consultation with the FAA.

6 Costs and Benefits

6.1 Introduction

6.1.1 This section presents an analysis of the costs and benefits delivered by the roadmap.

6.2 Costs

6.2.1 The study team has obtained estimates for the costs of implementing technologies for the roadmap from a variety of sources. The sources are described in annex D of the technology assessment document (P167D2020). Note that the derivation of costs is a difficult issue for a variety of reasons:

- The issue of cost is very close to the commercial interests of various suppliers and manufacturers so that it is not possible to provide full validation of the costs.
- Furthermore, commercially available products are only just becoming near to market and hence there are relatively few “price lists” available.
- The exact cost for a technology is generally dominated by installation, integration and downtime costs. This in turn depends on the type of aircraft being equipped.

6.2.2 The costs shown below are intended to be representative of the costs of retrofitting AT class aircraft. Costs for GA and smaller AT aircraft are likely to be considerably less.

6.2.3 The costs provided are based on retro-fit of existing aircraft. Airbus have indicated that their current avionics architecture is capable of cost-effective upgrades for VDL2 equipage. These reduced costs have been incorporated into the cost calculations. In aggregating costs, it has been assumed that half of the fleet are Airbus aircraft.

6.2.4 In the cost data presented below, it is assumed that VDL2 is used to support step 4, although this is discussed further later in this section.

6.2.5 The costs of ground infrastructure for steps 1 to 4 are shown in Table 6-1.

	VDL Mode 2	Mode S Enhanced Surveillance	Mode S Enhanced Surveillance	1090 Extended Squitter	1090 Extended Squitter	Total
	Assumes upgrade from ACARS	Assumes baseline of Elementary Surveillance. Required tranceiver & RCP exist	Assumes baseline of Elementary Surveillance. Assumes tranceiver & RCP require upgrade	Assumes upgrade from Enhanced Surveillance. Required tranceiver & RCP exist	Assumes upgrade from Enhanced Surveillance. Assumes tranceiver & RCP require upgrade	
Retrofit Technology costs (euros)						
Ground costs						
Hardware	60,000	0	0	75,000	75,000	135,000
Hardware installation and certification	12,000	0	0	15,000	15,000	27,000
Total initial costs per ground station (1 tx)	**72,000**	**0**	**0**	**90,000**	**90,000**	**162,000**
Total initial costs per ground station (2 tx)	132,000	0	0	165,000	165,000	297,000
Total initial costs per ground station (1 tx) with TIS-B electronics in transceiver where applicable (add 20% to gs cost)	72,000	0	0	108,000	108,000	180,000
Ground station maintenance costs per year (1 tx)	6,000	0	0	7,500	7,500	13,500
Ground station maintenance costs per year (2 tx)	12,000	0	0	15,000	15,000	27,000
Total number of ground stations to be installed	**150**	**150**	**150**	**150**	**150**	**450**
Total ground station costs excluding networks and centres (1 tx)	**10,800,000**	**0**	**0**	**13,500,000**	**13,500,000**	**24,300,000**
Total ground station costs excluding networks and centres (2 tx)	19,800,000	0	0	24,750,000	24,750,000	44,550,000
Total ground station costs excluding networks and centres with TIS-B electronics in transceiver where applicable (1 tx)	19,800,000	0	0	16,200,000	16,200,000	36,000,000

Table 6-1: Data link technology ground infrastructure costs for steps 1 to 4

6.2.6 The costs of airborne infrastructure for steps 1 to 4 are shown in Table 6-2.

	VDL Mode 2	Mode S Enhanced Surveillance	Mode S Enhanced Surveillance	1090 Extended Squitter	1090 Extended Squitter	Total
	Assumes upgrade from ACARS	Assumes baseline of Elementary Surveillance. Required tranceiver & RCP exist	Assumes baseline of Elementary Surveillance. Assumes tranceiver & RCP require upgrade	Assumes upgrade from Enhanced Surveillance. Required tranceiver & RCP exist	Assumes upgrade from Enhanced Surveillance. Assumes tranceiver & RCP require upgrade	
Airborne retrofit costs						
Hardware						
Transceiver x 1	49,400	not required	40,600	not required	40,600	90,000
Radio control panel (RCP) x 2	not required	not required	16,400	not required	16,400	16,400
GPS antenna x 1	not required	not required	not required	not required	1,500	750
CDTI x 2	not required	not required	not required	68,000	68,000	68,000
CMU new	47,000	not required	not required	not required	not required	47,000
FMS upgrade	not required	not required	not required	68,000	68,000	68,000
Integration, Installation & certification						
Installation Kit(s)	4,820	2,500	2,850	2,500	9,725	13,608
Service Bulletin	9,640	not required	5,700	not required	19,450	22,215
Man hours (80 euro/hour)	4,820	2,400	2,850	2,400	9,725	13,508
Operations and mantenance training						
Crew (6 crew) simulator training	not required	not required	not required	77,000	77,000	77,000
Crew (6 crew) theoretical training	not required	not required	not required	4,000	4,000	4,000
Simulator modification	not required	not required	not required	8,000	8,000	8,000
Total initial costs per aircraft (1 tx)	**115,680**	**4,900**	**68,400**	**229,900**	**322,400**	**428,480**
Maintenance costs per year (1 tx)	9,640	0	5,700	13,600	19,450	29,015
Total initial costs per aircraft (2 tx)	165,080	4,900	109,000	229,900	363,000	518,480
Maintenance costs per year (2 tx)	14,580	0	9,760	13,600	23,510	38,015

Table 6-2: Data link technology airborne infrastructure costs for steps 1 to 4

6.2.7 Other ground infrastructure developments are illustrated in Figure 6-1.

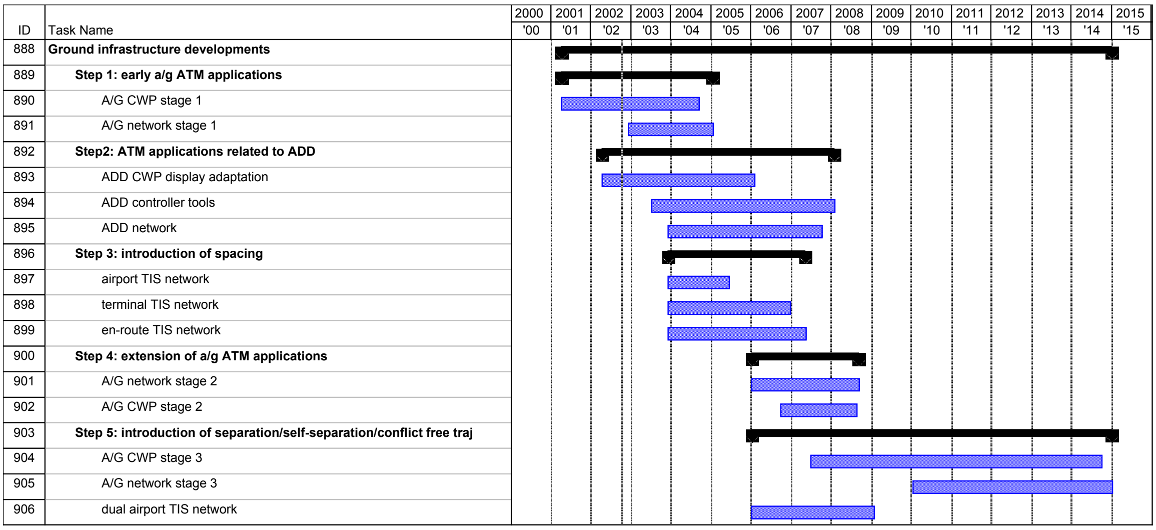

Figure 6-1: Ground infrastructure development to support roadmap

6.2.8 The associated costs are shown in Table 6-3.

Ground infrastructure developments	Cost
Step 1: early a/g ATM applications	
A/G CWP stage 1	
system cost (MEURO)	680
system maintainance (% of system cost)	10%
A/G netw ork stage 1	
system cost (MEURO)	228
system maintainance (% of system cost)	10%
data requirement per flight (kbyte)	2
data cost per kbyte (EURO)	0.52
Step 2: ATM applications related to ADD	
ADD CWP display adaptation	
system cost (MEURO)	680
system maintainance (% of system cost)	10%
ADD controller tools	
system cost (MEURO)	680
system maintainance (% of system cost)	10%
ADD netw ork	
system cost (MEURO)	11.9
system maintainance (% of system cost)	10%
data requirement per flight (kbyte)	0
data cost per kbyte (EURO)	0.52
Step 3: introduction of spacing	
Overall TIS-B netw ork	11.9
TIS-B server	30
airport TIS network	0
terminal TIS network	0
en-route TIS network	0
Step 4: extension of a/g ATM applications	
A/G netw ork stage 2	
system cost (MEURO)	0
system maintainance (% of system cost)	10%
data requirement per flight (kbyte)	0
data cost per kbyte (EURO)	0.52
A/G CWP stage 2	
system cost (MEURO)	680
system maintainance (% of system cost)	10%

Table 6-3: Costs for ground infrastructure to support roadmap (not including infrastructure to support data link technology)

6.3 Benefits

6.3.1 This section provides an analysis of the potential benefits of the roadmap. The following scenarios are presented:

- Baseline scenario: assuming that the timescales proposed in Phase 1 of the roadmap study are met by the delivery of appropriate technology.
- Failure to deliver benefits in step 4. As discussed in section 5, the number of channels required to support ATM applications in step 4 using VDL2 is likely to be high and not supportable within the current VHF band. Hence step 4 benefits are likely to be delayed until the implementation of alternative technology in step 5b.
- Delay to the roadmap timescales. Current Airbus plans are to support VDL2, Mode S Enhanced Surveillance and 1090 ADS-B out. However, the expected timescales are later than were derived in Phase 1.
- Higher traffic growth. Industry viewpoint is that traffic demand will increase more quickly than has been assumed in the STATFOR base case.

Baseline scenario

6.3.2 The analysis of Phase 1 results in timescales for provision of additional capacity by estimating a level of additional capacity supply for each step. Figure 6-2 illustrates the supply of capacity and traffic growth resulting from the phase 1 analysis.

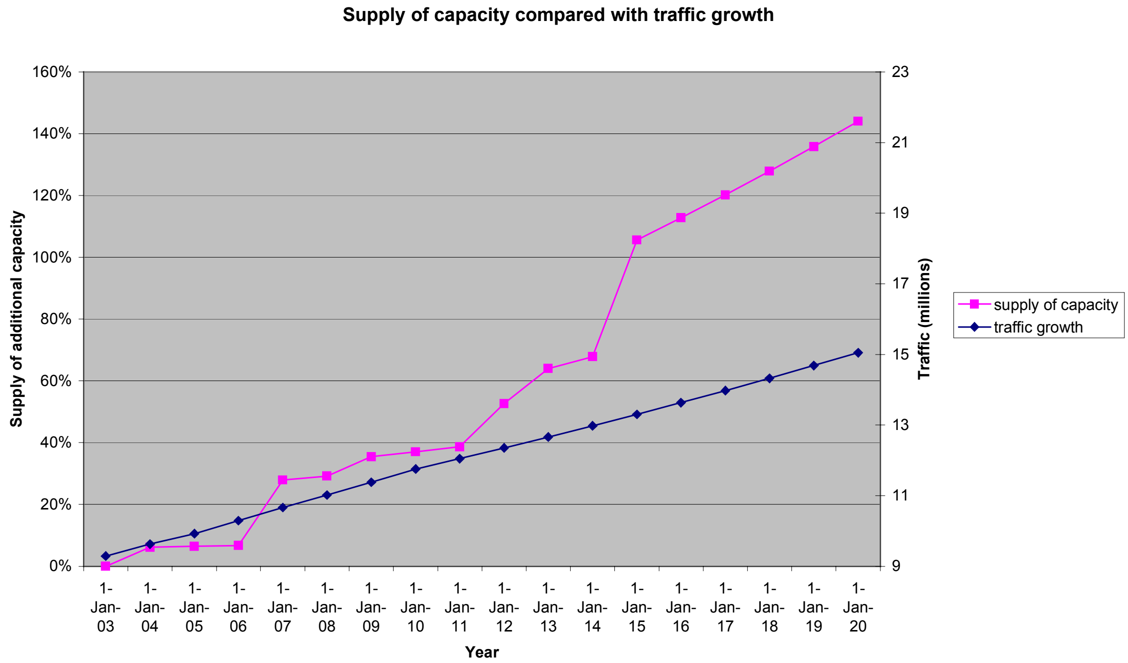

Figure 6-2: Supply of capacity compared with traffic growth

6.3.3 The graph takes account of capacity steps described in section 3 and takes account of equipage by assuming that 75% equipage is achieved at the end of the transition period associated with each ATM application. Traffic figures are taken from STATFOR base case data supplied by Eurocontrol. In the figure, the scales for supply of capacity and traffic have been set so that the percentage increase in each quantity is directly comparable.

6.3.4 The figure illustrates that until 2011, the supply of capacity through data link enabled ATM applications just exceeds the increase in demand. From 2012 onwards, the supply of capacity has the potential to increase faster than the underlying traffic demand. This delivers benefits as follows:

- it would lead to the potential for a significant decrease in user charges, reducing the cost of air travel, since the available capacity and associated costs could be spread over a greater number of flights;
- it provides the opportunity to reduce delays associated with peaks in the demand curve;
- it provides the opportunity to reduce the number of sectors required to support the demand and hence leads to the potential to control the growth or, or even reduce, the need for VHF voice channels;
- it provides additional capacity to meet an upturn in demand.

6.3.5 Furthermore, it can be seen that the real opportunities for a reduction in user charges and delays will result after 2014 with the widespread adoption of separation.

6.3.6 To illustrate these issues further, Figure 6-3 illustrates the growth in ground infrastructure necessary to provide sufficient capacity to meet demand. (For this simple illustrative analysis, the size of the ground infrastructure is set as proportional to the total revenue generated by user charges).

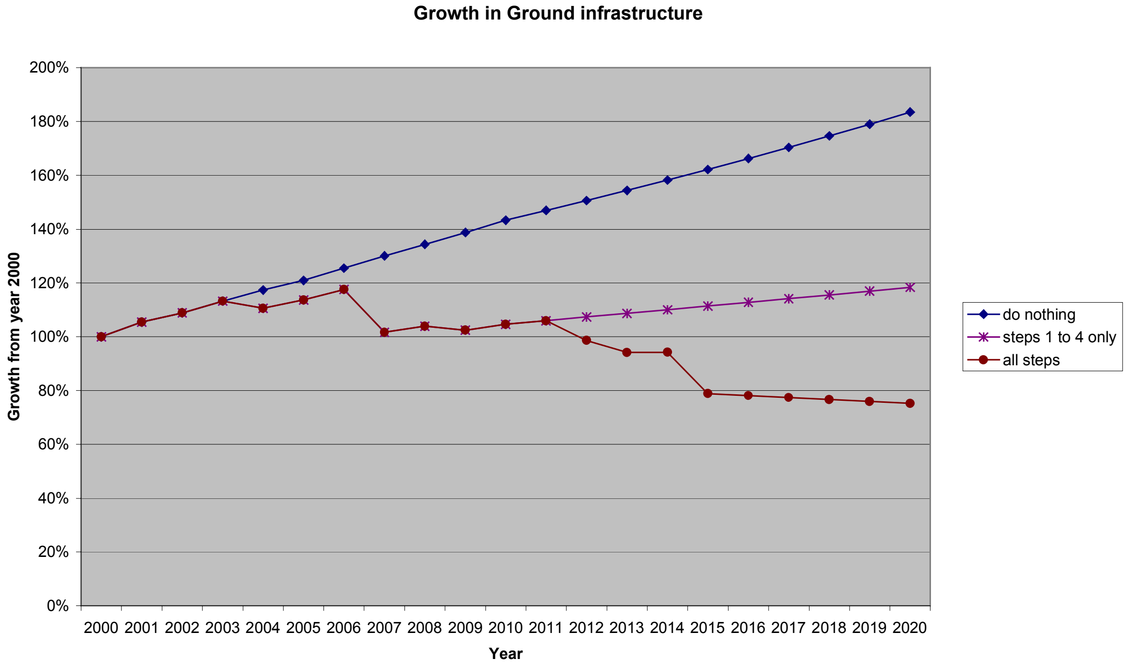

Figure 6-3: Growth in ground infrastructure

6.3.7 The “do nothing” curve illustrates that, if no additional capacity is provided via the implementation of new ATM applications, new sectors will have to be introduced at a rate equal to the increase in traffic. Aside from whether such a means of providing capacity could be sustained for many more years, it can be seen that the required infrastructure increases as the traffic growth rate (3 to 4% per year).

6.3.8 The other curves illustrate the impact of providing more capacity. Essentially, the same traffic is supported with fewer sectors and hence the growth in infrastructure is reduced. The implementation of steps 1 to 4 offers the possibility of maintaining the ATM system at the current total number of sectors. Moving to step 5, provides a substantial reduction in the number of sectors. In the early days, before the implementation of steps 1 and 2, there is likely to be a 10 to 15% growth in the number of sectors required to support the demand.

6.3.9 Figure 6-3 can also be used to estimate the number of additional VHF frequencies required. It can be seen that additional channels will be required in the short term, but that there is some prospect of keeping the total number constant at current levels by the completion of steps 3 and 4. A significant reduction would be possible through step 5.

Failure to deliver benefits in step 4

6.3.10 Analysis carried out within the study indicates that the number of channels necessary to support step 4 ATM applications is likely to be too high to be accommodated within the VHF spectrum. Hence, unless an alternative technology is implemented, there will be a delay to the delivery of step 4 benefits. The impact is illustrated in Figure 6-4.

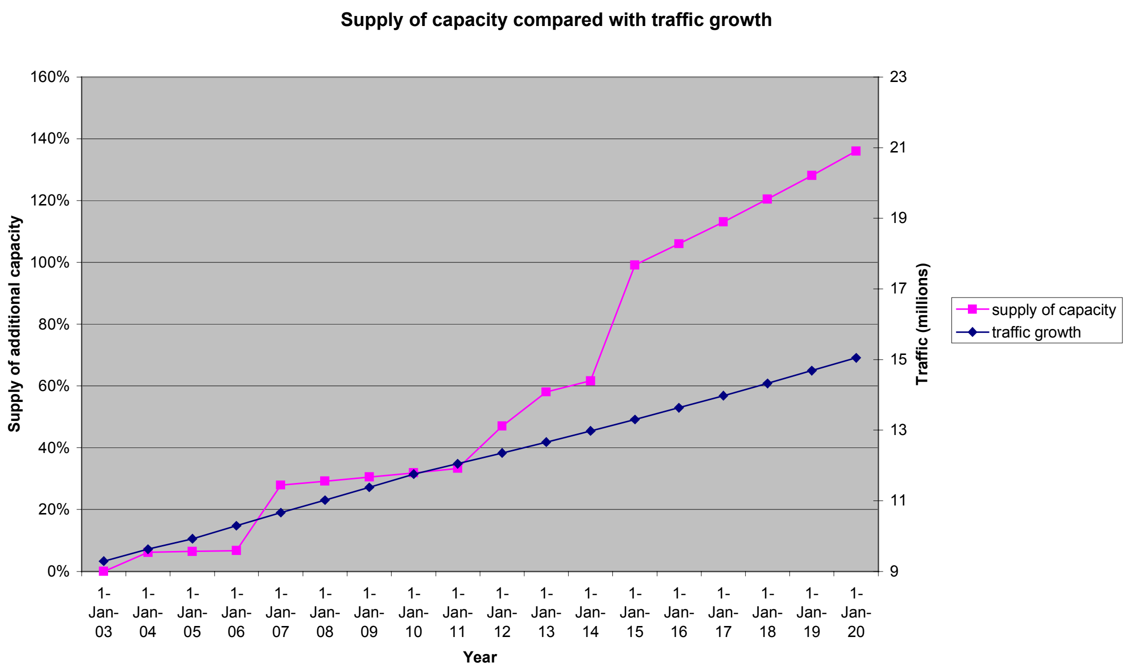

Figure 6-4: Supply of capacity in case where benefits in step 4 are not delivered

6.3.11 The impact is that the capacity provided by data link enabled ATM applications only just follows the demand curve. A consequence of this is that current levels of delay associated with peaks in demand are unlikely to decrease.

Delay to the roadmap timescales

6.3.12 Timescales established in Phase 1 were based on user needs for additional capacity to meet demand. The study obtained timescales for implementation of data link technology based on the current plans for equipage of Airbus aircraft and from input obtained from stakeholders during the public consultation process.

6.3.13 Airbus expect the following milestones for delivery of the roadmap milestones:

- availability of VDL2 ATN equipped aircraft from 2003 with 75% equipage achieved by 2008 (compared with 2002 and 2005 respectively assumed in Phase 1)
- availability of Mode S enhanced surveillance and 1090 ES ADS-B out equipped aircraft from 2003 with 75% equipage achieved by 2008 (comparable with the years assumed in Phase 1)
- availability of 1090 ES ADS-B out equipped aircraft from 2007 with 75% equipage achieved by 2012 (compared with 2003 and 2007 respectively assumed in Phase 1)
- pro rata delay of technology support for steps 5 noting that Airbus currently has no firm plans for how to support this step.

6.3.14 Table 6-4 illustrates these timescales and those obtained from other stakeholders and compares them to those derived during phase 1.

ATM application step	Phase 1 timescales (“operational need”)	Stakeholder comments (“availability of technology and infrastructure”)
Step 1: early air/ground ATM applications	**2006** (75% equipage)	**2011/2012** (SITA) (75% equipage)
Step 2: ATM applications related to downlink of air-derived data	**2008** (75% equipage)	**2006** (Airbus) (>75% equipage)
Step 3: introduction of spacing	**2010** (75% equipage)	EVA only – **2007** (Airbus) Final approach spacing + EVA– **2008** (Airbus) Other spacing – **2012** (Airbus) (All dates – start of equipage)
Step 4: extension of air/ground ATM applications	**2009/2010** (75% equipage)	2012 + (based on timescales for step 1) (start of equipage)
Step 5a: introduction of separation and self-separation	**2013+** (75% equipage)	Oceanic and remote –**2012** (Airbus) Terminal an en-route – **2018** (Airbus) Sole means surveillance –**2017** – **2019** (Airbus) (All dates – start of equipage)
Step 5b: conflict free trajectory negotiation.	**2013+** (75% equipage)	**2011** (Airbus) (start of equipage)

Table 6-4: Timescales from Phase 1 and for implementation plans

6.3.15 With the exception of step 2, these timescales lag significantly behind those established in Phase 1.

6.3.16 Achievement of the capacity supply shown in Figure 6-2 will require investment and a rapid equipage within the fleet. These factors act as barriers to achievement of the capacity supply. To illustrate this, consider the adoption rate for operators using Airbus aircraft.

6.3.17 The impact on the supply of capacity is illustrated in Figure 6-5.

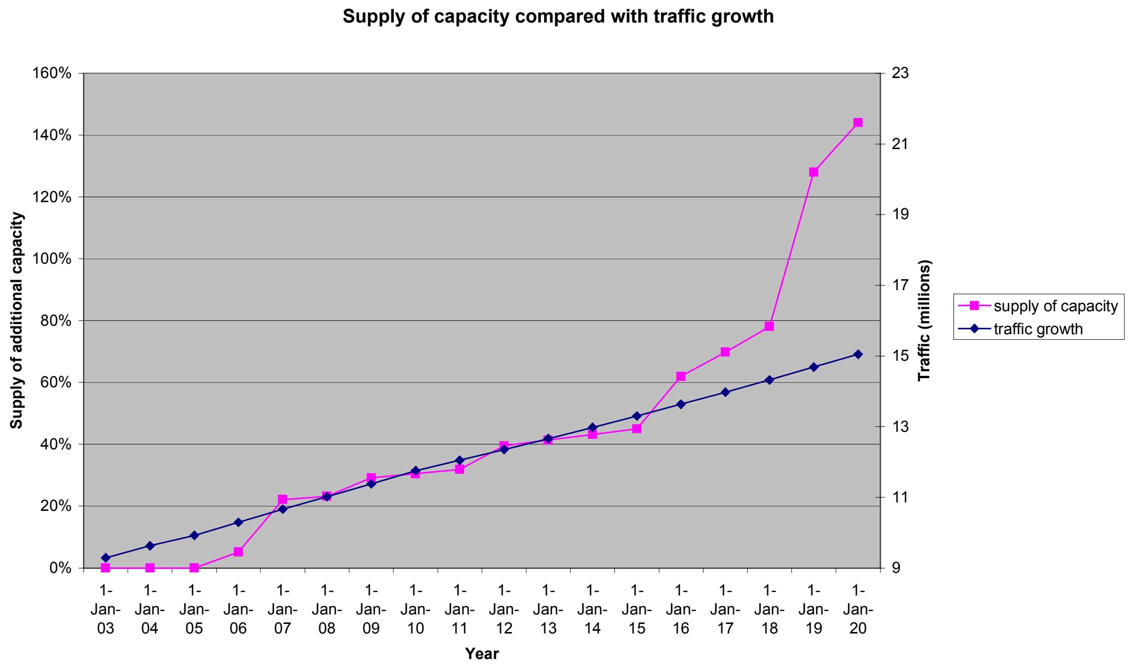

Figure 6-5: Supply of capacity following Airbus baseline

6.3.18 The figure illustrates that the supply of capacity now follows the increase in demand and hence, at the very least, there is the opportunity to maintain the current level of service and user charge. Note however that real change in the manner in which ATM is provided is delayed until post 2015. Specifically:

- It is unlikely that sufficient capacity will be provided to make any impact on the current high rate of delay experienced by air travellers in Europe.
- There is no contingency to respond to an upturn in traffic demand. Note that the study has used Eurocontrol STATFOR base case figures which provide for a doubling of traffic levels by 2020. The IATA and Airbus expectation is that the increase in demand will be greater than this, amounting to three times the current levels in 2020.
- Any shortfall in capacity can only be met by an increase in sectorisation, which in turn increases the costs of ground infrastructure and the need for additional VHF channels.

6.3.19 The growth infrastructure corresponding to the Airbus baseline is illustrated in Figure 6-6.

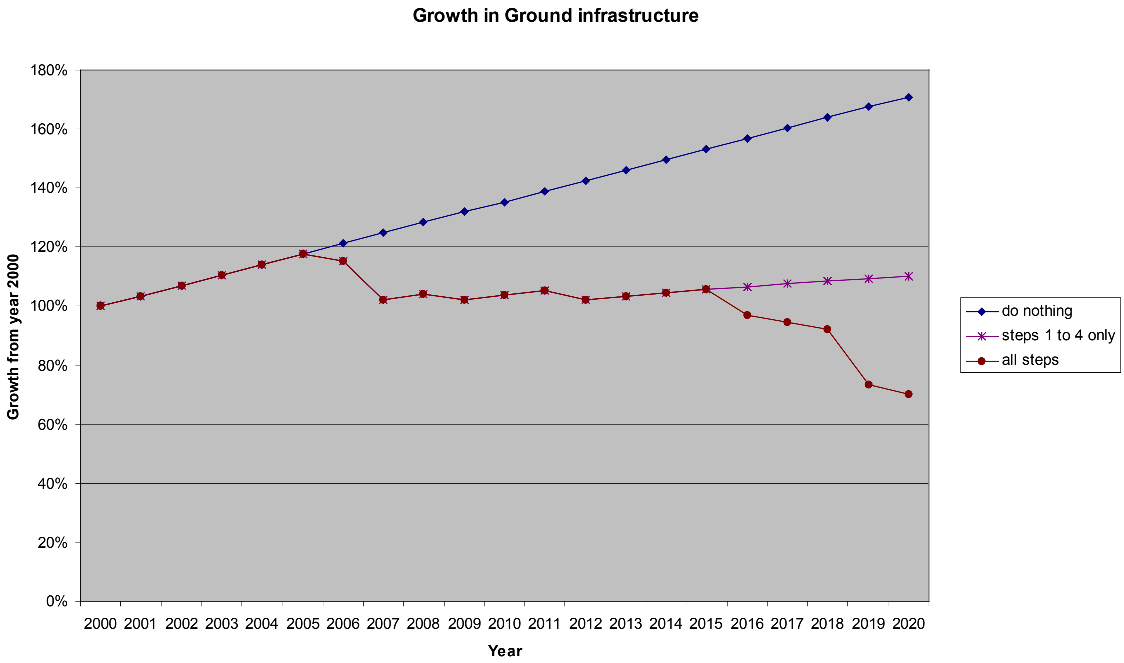

Figure 6-6: Growth in infrastructure for Airbus equipage plans

6.3.20 Compared to Figure 6-3, based on Phase 1 timescales, the Airbus baseline line results in:

- a higher initial growth rate in infrastructure requiring up to 20% more sectors and VHF channels
- a delay in achievement of a whole scale reduction in the infrastructure in the period after 2015.

6.3.21 The timescales for implementation of the ATM applications derived in Phase 1, and agreed during stakeholder consultation, provided shorter timescales for ATM applications based on user needs for additional capacity. This was particularly true for Step 3, which itself is seen as an essential pre-cursor to the larger capacity enhancing steps in Step 5. The Community should therefore consider the need for more rapid implementation of the timescales for implementation of data link technology.

Impact of higher traffic growth rates

6.3.22 During the study, both IATA and Airbus have indicated their expectation of a higher traffic growth rate than is indicated in STATFOR base figures. They expect traffic to have reached three times current levels in 2020. Figure 6-7 illustrates the impact of this.

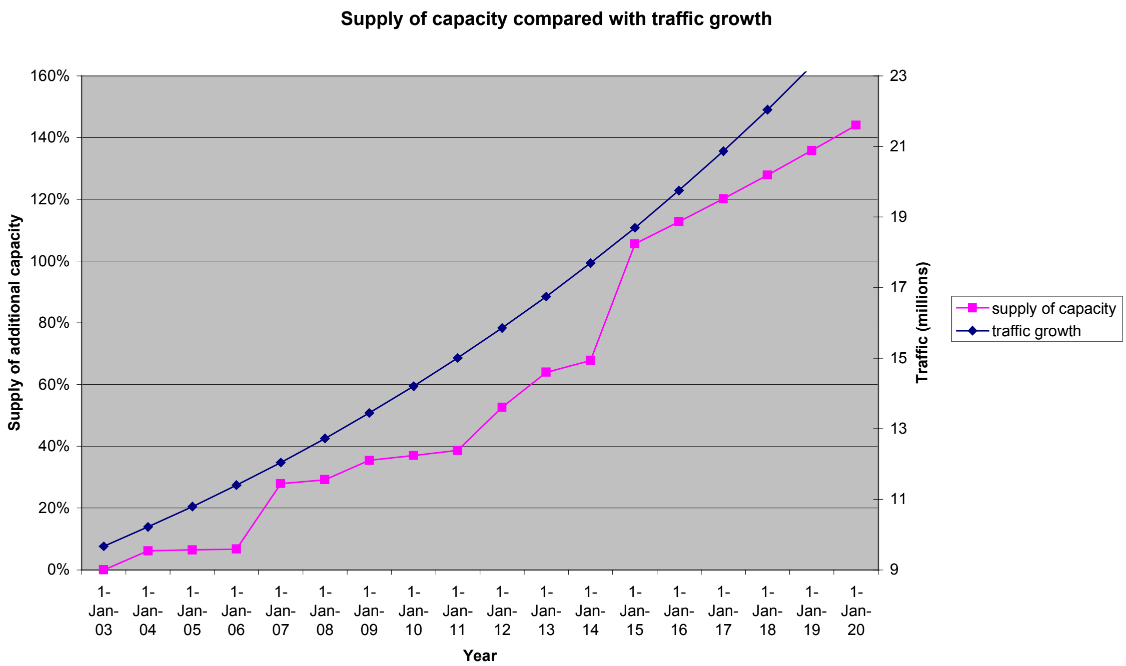

Figure 6-7: Supply of capacity against demand for higher traffic growth

6.3.23 The supply of capacity now substantially lags behind the traffic growth and hence the demand could only be met through further (and probably impractical) re-sectorisation.

6.3.24 The community needs to decide if it requires a more rapid progression towards the provision of capacity. The study team believe that that should be the objective. However, this will be obtained only by stimulating equipage at a rate faster than that represented by the Airbus baseline. This is discussed further in Section 7.6.

6.4 CBA summary and sensitivities

6.4.1 To illustrate the comparison between costs and benefits for steps 1 to 4, a simplified calculation has been carried out. Some broad assumptions have been made:

- The supply of additional capacity results in the spread of current revenue derived from user charges over a greater proportion of traffic.
- Similarly the supply of additional capacity results in a reduction in the costs of delays and route inefficiencies per aircraft pro rata with the additional capacity provided.
- The phasing of costs follows a progression from 0% equipage when a particular technology becomes available to 75% at the end of the transition period. Thereafter, equipage increases to 100% by 2020.

- No discount has been made for any investment that might be justified on a basis of provision of AOC services (ie the full cost of equipage is included)[34].
- the calculations include a provision for upgrade of ATC systems based on the figures in Table 6-3.
- the cost of data transfer across commercial networks has been included.

6.4.2 The results are shown in Figure 6-8 for an equipage rate based on timescales expected by Airbus. Note that data covers steps 1 to 4 only.

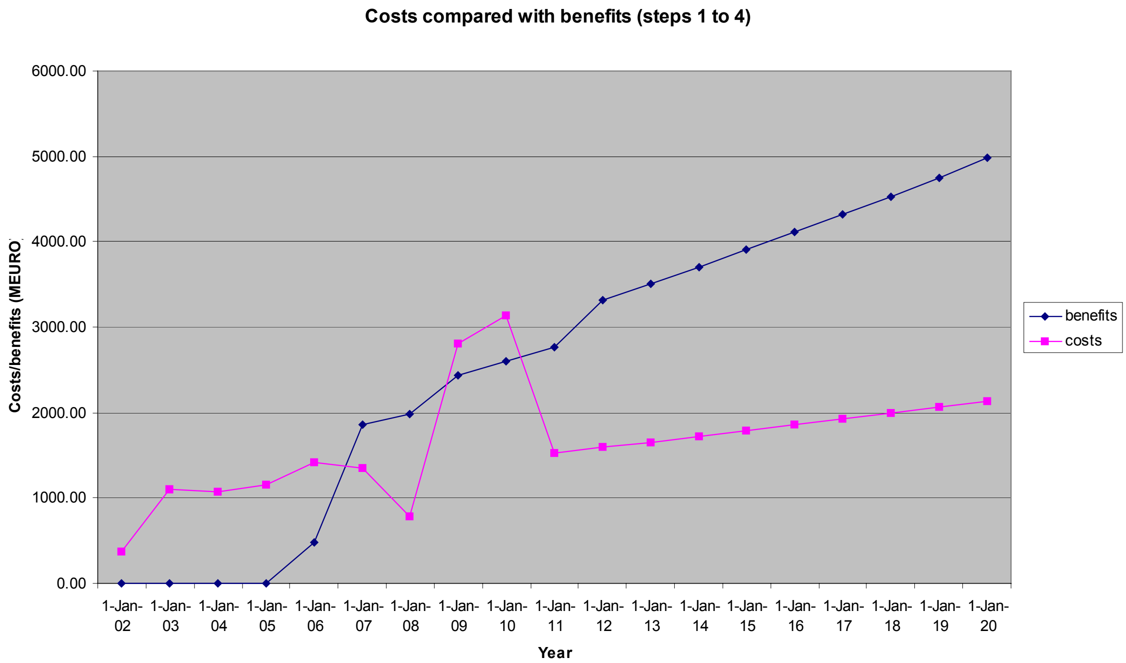

Figure 6-8: Benefits and costs associated with supply of capacity

6.4.3 The net present value of benefits minus costs has been calculated using a reference year of 2002, a discount factor of 8% and a project lifetime to 2020. The total NPV is 9.9BEURO.

6.4.4 Three other scenarios were analysed during the work:

- a scenario based on the original timescales from phase 1. The NPV is 10.6BEURO. The NPV is larger because although investment is made earlier, this is offset by achieving benefits earlier.
- a scenario based on the original timescales from phase 1 but with no benefits delivered in step 4. The NPV is 9.7BEURO.
- a scenario based on the original timescales from phase 1 but with the addition of VDL 4 supporting ATM applications in step 4. The NPV is 8.8BEURO. Note also that further benefits may arise because of the earlier provision of capacity enhancements:

[34] Comments were received that since the communications service providers and airlines are making significant investments in VDL2 for AOC that will be leveraged to support ATS applications it be correct to make provision of this discount in the CBA.

- reduction in the need for new sectors because a greater rate of increase in capacity is achieved (see Figure 6-2)
- hence a reduction in the need for VHF spectrum
- greater ability to deal with a) peaks in demand and b) a faster increase in demand than in the STATFOR base case
- earlier confidence building leading to new concepts such as separation in Step 5 earlier than in the Airbus baseline.
- Note that in the case of higher traffic growth, the NPV of this scenario rises to 12.7 BEURO, providing support for the introduction of an additional VDL.

6.4.5 Safety benefits will be available as summarised in Table 6-5.

Step	Benefit	Phase 1 timescales	Airbus timescales
		initial adoption – widespread usage	initial adoption – widespread usage
1	Reduced risk of misunderstanding between controllers and pilots	2003 – 2005	2005 – 2008
2	Enhanced safety net tools	2006 – 2008	2006 – 2008
3	EVA, enhanced visual approaches and traffic situational awareness	2006 – 2007	2009 – 2011
4	Further reduction in misunderstanding between pilots and controllers	2008 – 2009	2008 – 2009

Table 6-5: Timescales for introduction of safety benefits

6.4.6 It is concluded that on the basis of ATC related benefits, there appear to be sufficient benefits over a project lifetime to 2020 to justify equipage in steps 1 to 4. This does not take account of potential AOC benefits that result from adopting data link technology.

6.4.7 A number of issues are raised by the results of the costs and benefits analysis:

- The main steps in the roadmap that deliver a large positive NPV are steps 1, 2 and 5.
- The results of Phase 1 indicate that the ATM applications are required sooner than is currently being planned generally within the industry. The results of the costs and benefits analysis indicates that earlier implementation of the first 4 steps in the roadmap generates sufficient benefits to offset the earlier investment. The Community should therefore consider the extent to which it wishes to accelerate the timescales of the roadmap.
- The delivery of benefits in step 4 is judged risky for a solution based on VDL2 only because of spectrum shortage. However, the benefits of step 4 alone are insufficient on their own to justify the addition of a second VDL. Hence it is likely that such a step could only be justified if the same VDL link also plays a part in the delivery of benefits in step 5. This suggests that the best candidate link for step 4 would be VDL4 since it also has the potential to support broadcast applications in step 5. Note that such a solution must be considered in the light of whether the resulting efficiencies in spectrum can be managed in an environment dominated by Mode 2 and voice. The

technical evaluation of the solution must also consider the safety implications of both point-to-point and broadcast services being supported on the same media.

- A negative NPV has been obtained for all of the scenarios considered above in step 3. This is not surprising because the adaptations to the avionics for broadcast applications have high cost, but the benefits of step 3, broadly equivalent to ADS-B package 1 applications are insufficient to justify this cost. However, two issues are considered by the study team of high importance for consideration by the community:
  - the analysis has not considered terminal area and airport capacity benefits and has not quantified safety benefits delivered in step 3. These are likely to be significant and may in themselves justify the implementation of step 3.
  - the ATM applications in step 3 are considered an essential pre-cursor of the applications in step 5a. Step 5a delivers high levels of benefit but represents a change of control paradigm which, to some extent, is de-risked by the implementation of step 3.

6.4.8 Note that to realise the benefits claimed a significant number of community actions are required urgently. These are discussed in section 7.

7 Community measures

7.1 Introduction

7.1.1 The ATM and data link technology roadmap presented in this document provides the potential to deliver significant levels of additional capacity which can meet the growth in traffic demand and provide “headroom” to deal with the fundamental problems affecting European air transport. These include:

- high user charges – the roadmap demonstrates that significant reductions in user charge will result if the roadmap timetable is achieved;
- unacceptable delays and inefficient routing, both of which will only become worse unless action is taken – the roadmap provides additional capacity to deal with these issues;
- a shortage of VHF spectrum – the roadmap transfers communication to data and, through the mechanism of increased capacity leading to more efficient sectorisation, reduces the need for additional channels, although this may be offset by requirements from new airports.

7.1.2 Furthermore, the investment necessary is offset by benefits which result in a positive NPV for the roadmap.

7.1.3 Note however that the arguments presented have been kept at a European level. The study team believe that attempts to construct a regionally constrained business case to justify airborne equipage is bound to fail. It is the netting of all benefits over operations within the whole European regions that results in an overall positive business case. It is therefore crucially important that the key issues in achieving the timescales are addressed at a European level with appropriate coordination and legislation.

7.1.4 From the point of view of achieving the roadmap timescales, there are three issues of primary importance:

- completion of urgent actions to support the decision making process. The focus is to enable the community make an decision, within 2003, on the appropriate way forward for steps 1,2 and 3.
- optimisation of the availability of capacity to the traffic demand. In effect this means arranging sectorisation so that best use is made of ATM resources including staffing and spectrum. The Single Sky provisions provide an important backdrop to this optimisation allowing sectorisation across national boundaries. The optimisation must be accompanied by downward pressure on user charges so that operators feel immediate benefit from the investment in new technology. This issue is discussed further in section 7.3.
- rationalisation of VHF spectrum. The VHF spectrum reserved for aviation use is in desperately short supply. Increase in traffic places further demands for voice channels. In addition, transfer to data simply adds an initial requirement for channels with no immediate gain from the channels reserved for voice. Optimisation of sectorisation will help the situation to some extent but a thorough Europe-wide review is urgently needed. The first 10 years of the roadmap depends on transfer of services to data channels within the VHF spectrum. This issue is discussed further in section 7.4.

7.1.5 There are many other important issues to address and these are also discussed in this section.

7.2 Urgent actions supporting decision making for steps 1, 2 and 3

7.2.1 The community needs to decide whether it supports one or both of the proposed routes for steps 1, 2 and 3.

7.2.2 The route based on VDL2, Mode S EHS and 1090 ES is seen by some stakeholders as a pragmatic choice to deliver early benefits, although concerns with this route, raised during the public consultation process, need to be addressed by the community. In order to reduce the total costs it may require appropriate exemption policies exempting non frequent users of the core airspace whenever possible.

7.2.3 If both routes are supported it is important to determine under which conditions co-existence of data link technologies is possible and whether the disadvantages outweigh the advantages. The advantage is that, potentially, the requirements expressed by all airspace users including GA can be accommodated. The disadvantages include additional costs associated with supporting two routes and a requirement for additional VHF spectrum that might otherwise be reserved for just one link.

7.2.4 There is therefore an urgent need to make a decision on the way forward for the data link roadmap. A number of actions to assess outstanding technical issues must be completed before such a decision can be made. Because of the urgency of the situation, these actions must be completed before the end of 2003. These urgent actions, which were agreed at the second stakeholder workshop, are summarised below:

- Large-scale simulations of VDL2 performance to support determination of frequency requirements for VDL2. Eurocontrol expects to complete such simulations in mid-2003.
- Detailed analysis on the performance of 1090 ES in dense traffic/high interference environments, including the airport surface, and on the feasibility to certify it for ADS-B applications.
- Detailed studies to resolve the remaining technical issues surrounding VDL3 and 4. This should include determination of performance, such as effective data rate and guard bands using high-fidelity large scale simulations to support the determination of frequency requirements, and work on onboard architectures.
- The specification of VHF DSB-AM communications radios should be re-visited to see if interference from voice and VDL can be reduced.
- Development of frequency planning criteria and assignments for VDL3 and VDL4.
- Investigation of the availability of a frequency for UAT.
- Raising the need to consider technologies operating outside the VHF band at the World Radio Conference (WRC) in 2003 in order to begin any necessary processes to obtain spectrum allocation.

7.2.5 The results of this work should be used to determine which ATM applications could be delivered by the data link technologies as a function of traffic growth, equipage and spectrum availability.

7.3 Rationalisation of sectors

7.3.1 The key driver for investment in data link technology is to support the provision of airspace capacity in Europe. Current measures to provide additional capacity generally result in the formation of more and smaller sectors. Such measures inevitably lead to an increase in infrastructure costs. It is also generally accepted that there are limits to the division of sectors, arising from an increase in the workload associated with coordinating between the sectors. It is clear therefore that without new concepts and supporting technology, European airspace will suffer a combination of limited capacity and escalating costs.

7.3.2 The measures proposed in the ATM application roadmap can lead to enhanced capacity and bounded investment costs. However, it is necessary that the sectored structure is optimised to make best use of current and new capacity when it is available. Appropriate measures include re-drawing sector boundaries according to traffic patterns rather than national boundaries, a development made easier within the provisions of the European Single Sky Initiative.

7.3.3 It is also important to rationalise sectorisation and take advantage of new capacity in order to reduce the need for new VHF voice channels.

7.3.4 It is therefore essential that future utilisation of capacity is planned on a European basis and that a suitable coordination body be set up to oversee this.

7.4 Spectrum planning

7.4.1 The early stages of the roadmap require the widespread introduction of data link into the already congested VHF band. As the usage of the data link services increases, calculations indicate that the number of channels required will increase rapidly. At the same time, the requirement for VHF channels to support voice services will increase. Current estimates are that the number of channels for voice will increase by just under 4% per year and, although some of this growth can be accommodated by further migration to 8.33kHz channel spacing, it is likely that saturation will occur in the period 2010 to 2015.

7.4.2 The study team has concluded that the only short-term option for introducing data link services involves introduction of technology that requires VHF spectrum. Alternative technologies require more development time and will only become practical for steps 4 and 5. Hence, VHF spectrum is required for data services if the ATM application roadmap is not to be delayed.

7.4.3 Current frequency planning focuses on providing 4 channels for VDL2 at the top of the communications band, only one of which is initially intended for ATS services Two channels are being considered for VDL4 near the top of the communication band and there is also consideration of two channels within the navigation band. All of these would be intended to support broadcast services and not point to point.

7.4.4 Even if the initial allocations are established, they will quickly become inadequate to support the growth in services.

7.4.5 The Community therefore needs urgently to consider the issue of VHF spectrum allocation. Specific actions include:

- carry out a “root and branch” survey of how allocations are carried out within Europe, seeking opportunities to gain efficiencies by coordinating allocations across Europe rather than relying on regional allocation schemes.
- work closely with planning bodies responsible for re-sectorisation so as to produce sector plans that reduce the need for voice channels
- work to reduce the need for AOC voice communication, seeking to move voice to data.

7.4.6 Other spectrum issues include:

- Co-ordination with the navigation domain on frequency availability for UAT and VDL4 for surveillance applications. The European navigation strategy [257] includes the decommissioning of VORs but the increased use of DMEs to support RNAV operations. The latest estimate is that 180 to 200 additional DMEs will be required by 2010 [258]. This means that suitable VHF frequencies are more likely than suitable UAT frequencies.
- The need to protect frequencies for future technologies.
- Note that for SATCOM the existing L-band frequency is very important as the other (higher bandwidths) suffer reduced performance in the rain. The existing allocation is under threat from other mobile users.

7.5 Business case development and monitoring

7.5.1 The cost/benefit justification presented in this document provides an outline case based on very broad assumptions. It indicates that there is a positive case for the roadmap but it has been noted elsewhere that the benefit side of the case requires close monitoring and pro-active management to ensure delivery.

7.5.2 The Community must establish a firm business case for the roadmap and establish performance indicators to assure its delivery. It is important that the business case is established across all measures proposed in this document and also take account of other major infrastructure investments such as RNAV.

7.5.3 The main purpose of the business case is to provide operators with clear visibility of progress achieved against targets. In effect this means that there must be visible beneficial change in key indicators which include:

- a reduction in user charge;
- a decrease in delay;
- a decrease in route extension.

7.5.4 An appropriate focus for the business case work could be the Eurocontrol PRC, linking the evolution of the roadmap closely to the current monitoring of ATM performance.

7.5.5 A key further aim of this work will be to inform decision makers within operators and ANSPs as to the most cost beneficial technology choices compatible with the aims of the overall roadmap. Hence the work must keep up to date information on costs.

7.5.6 Also provide input into user charge setting including potential differential charging used as a mechanism for encouraging equipage.

7.6 Equipage and potential mandates

7.6.1 The timescales for equipage of each technology are illustrated in Figure 7-1.

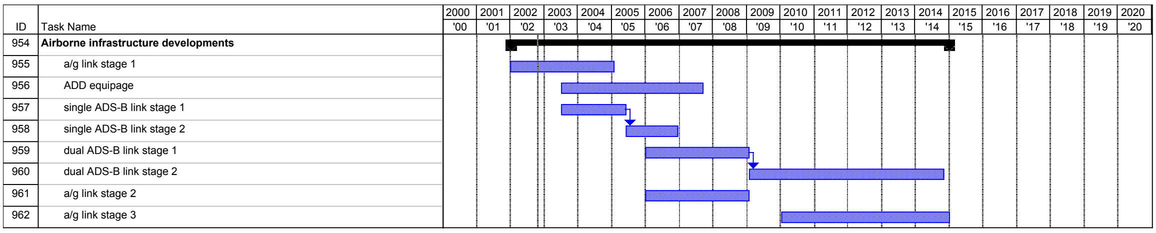

Figure 7-1: Timescales for equipage

7.6.2 The timescales are derived by taking the time from product availability to the point at which the first ATM application requiring the technology becomes operational. It has been assumed that the equipage at the operational point is 75%.

7.6.3 In general terms, the ATM applications required in steps 1 to 4 have a low safety criticality and do not require full equipage to deliver benefit. For step 5 however there is greater safety criticality and higher equipage levels are required and interoperability between aircraft. The Community should therefore consider a mandate for the later technology steps. The aim should be to establish a mandate by 2007 for equipage by 2012.

7.6.4 During the first and second steps, fleet equipage may follow different paths:

- major carriers operating worldwide will support 1090 ES and Mode 2;
- some regional carriers operating within Europe may choose to equip with VDL4 only.

7.6.5 The result will be a mixed fleet unless Europe takes steps to mandate one solution only. The study team believe that since none of the technology options can deliver all of the ATM applications required in the period after 2010, it is undesirable to force a mandate for the technologies required for steps 1 to 4. The implementation of a/g data link technology is driven by a parallel need to support AOC services and there can be reasonable expectation that significant equipage levels will result.

7.6.6 The incentive to equip with ADS-B technology is not as strong. One approach couples 1090 ES equipage with a Mode Enhanced Surveillance upgrade for which some states are considering a mandate. Operators may therefore choose to provide the full 1090 ES capability (ie CDTI + ADS-in) although the costs involved are still considerable. Note that ADD benefits in step 2 could be provided by ADS-B out provided by 1090 ES or VDL4. Hence the need for the Mode S enhanced surveillance upgrade is not definite. Hence, the Community needs to decide if such a mandate is necessary.

7.6.7 Industry surveys indicate that the capability for upgrade to support the following systems will be included in new aircraft deliveries:

- VDL2
- 1090 ES

7.6.8 For VDL2, as Pioneer Airlines, SAS and Lufthansa have committed 20 aircraft each to the Link2000+ program.

7.6.9 However, there are no plans to retrofit 1090 ES systems and even the upgrade costs are significant. Hence, the Community must do something else to encourage equipage to support ADS-B for Step 3.

7.6.10 Possible measures include:

- introduce differential route charges with discounts for equipped aircraft.
- consider mandating Mode S elementary plus Air Derived Data but with a choice of technologies for example Mode S EHS, 1090 ES or VDL4)

7.7 Implementation of pilot projects

7.7.1 The measures proposed in the roadmap involve significant changes to the manner in which ATM is carried out. Some measures involve automation of current practice whereas others involve a delegation of aspects of control to the pilot. For many of these new measures, a period of confidence building will be necessary. It is highly unlikely that widespread adoption of some of the ATM applications will take place throughout core European airspace unless measurable results have been obtained under monitored conditions.

7.7.2 Therefore it is proposed that implementation is encouraged through a number of pilot projects. These projects should focus on regions where the following conditions can be fulfilled:

- low to medium traffic density
- local pockets of high equipage with a particular data link technology
- low cost adaptation of existing control suites is possible or where introduction of a new concept is timed to coincide with a current system update cycle.

7.7.3 The most promising areas are probably in and around airports which act as a hub for a regional fleet.

7.7.4 The timescales for potential pilot projects are illustrated in Figure 7-2.

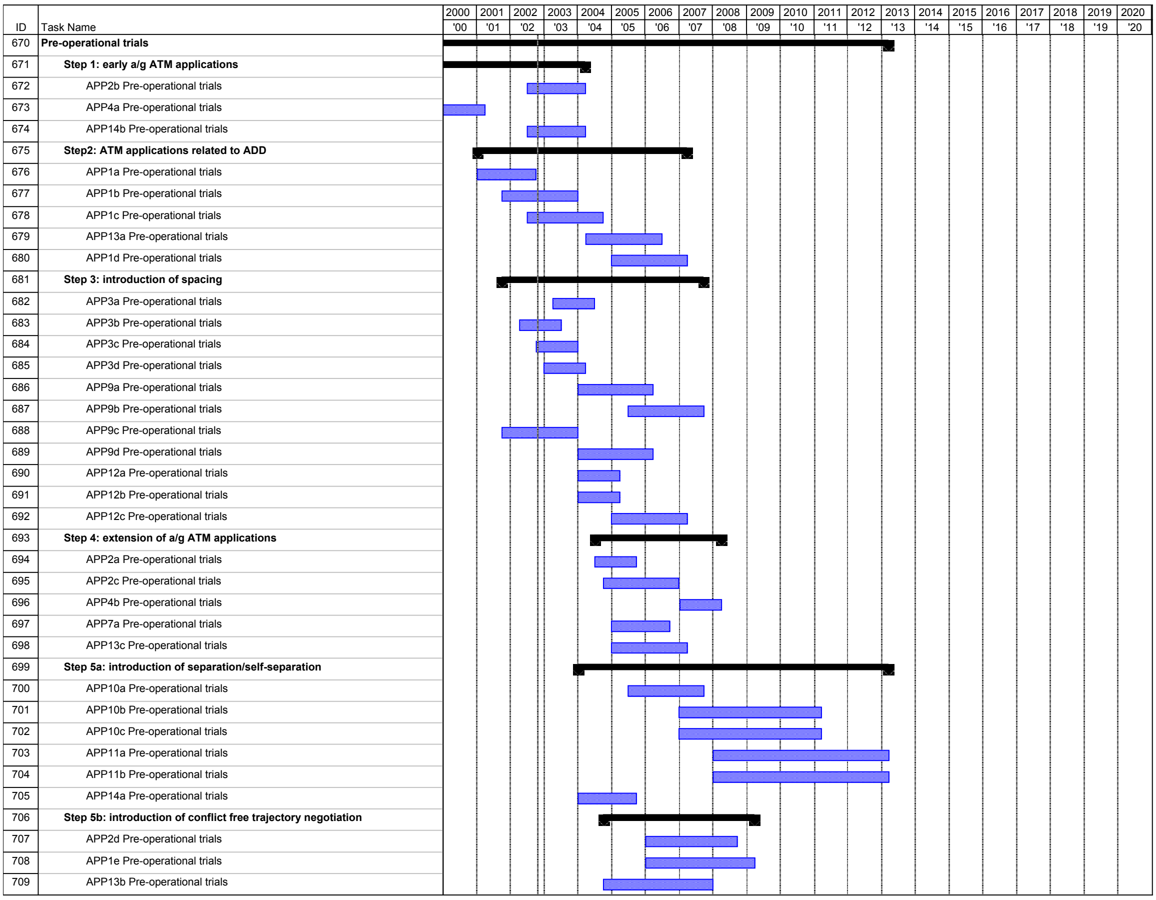

Figure 7-2: Timing for pre-operational trials (pilot projects)

7.7.5 Key areas that need to be addressed for pilot projects are:

- progress the Link2000+ programme in order to demonstrate benefits from step 1. A suitable implementation area is based around the Maastricht ATCC which is already planning to support Link 2000+ services.
- to facilitate the urgent introduction of ADD concepts. The benefit analysis carried out within the study indicates that significant benefits can result from the use of airborne derived data Furthermore, the required technologies and concepts are sufficiently mature to enable implementation to start now.
- proving of EVA and spacing applications. The capacity benefits associated with EVA and spacing in the en-route area are assessed to be small. However, significant safety and capacity benefits are available in the airport and terminal regions. Furthermore, spacing in en-route regions is seen as n essential pre-cursor to the later transition to separation. Hence, it is important that experience is gained in order to gain sufficient understanding of air-air applications to inform the planning of later concepts. Key areas for pilot projects are those regions currently involved in the NUP, MFF and CEAP projects where there is already a high level of commitment to air-air applications.

7.8 Standardisation, regulatory and airspace policy issues

7.8.1 General

7.8.1.1 Introduction of new concepts and supporting technologies will require:

- clear standards for ATM applications and technologies
- a process for gaining approval for new operations
- confidence building measures to re-assure regulators that levels of safety are maintained
- confidence building measures to re-assure airlines and ANSPs that capacity benefits are realisable.
- timely approval of new concepts and technologies.

7.8.2 ATM application standards

7.8.2.1 The required progress on establishing ATM applications standards is illustrated in Figure 7-3.

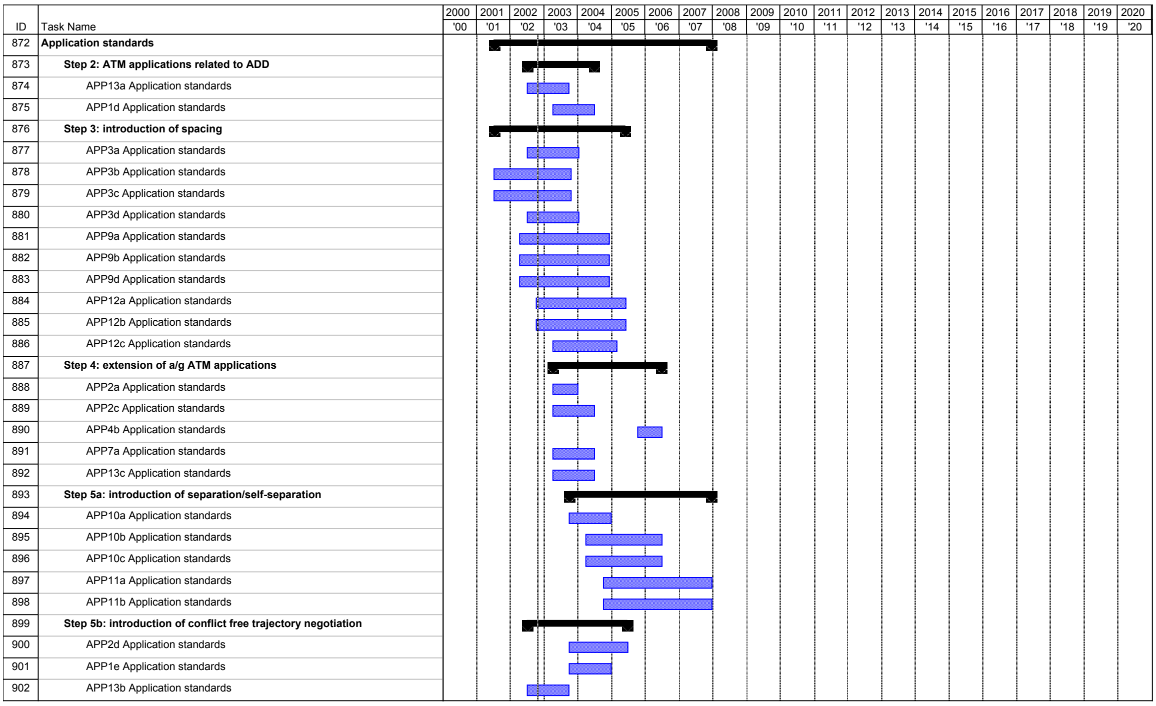

Figure 7-3: Timescales for establishing application standards

7.8.2.2 A key area is to establish clear MASPS for ADS-B related applications. These should initially focus on requirements for EVA and spacing and later be extended to include separation and self-separation. This work has been started by EUROCAE with the intention of providing ASA MASPS supporting Package 1 applications by the end of 2004.

7.8.2.3 Particular issues that must be addressed in this work include:

- The level of FMS integration necessary to support spacing applications.
- The ability of TIS-B, in particular to support spacing. In particular can spacing be carried out between aircraft equipped via the two routes used for step 3, supported by a dual TIS-B network.
- Concept and operation for separation, including whether there is a need for a dual ADS-B link and for an air-air point to point link.

7.8.2.4 This study does has not address the institutional and liability issues associated with any delegation of responsibility for maintaining separations to the flight deck. These issues need to be resolved and could affect timescales.

7.8.3 Equipment standards

7.8.3.1 The required progress on establishing equipment standards is illustrated in Figure 7-4.

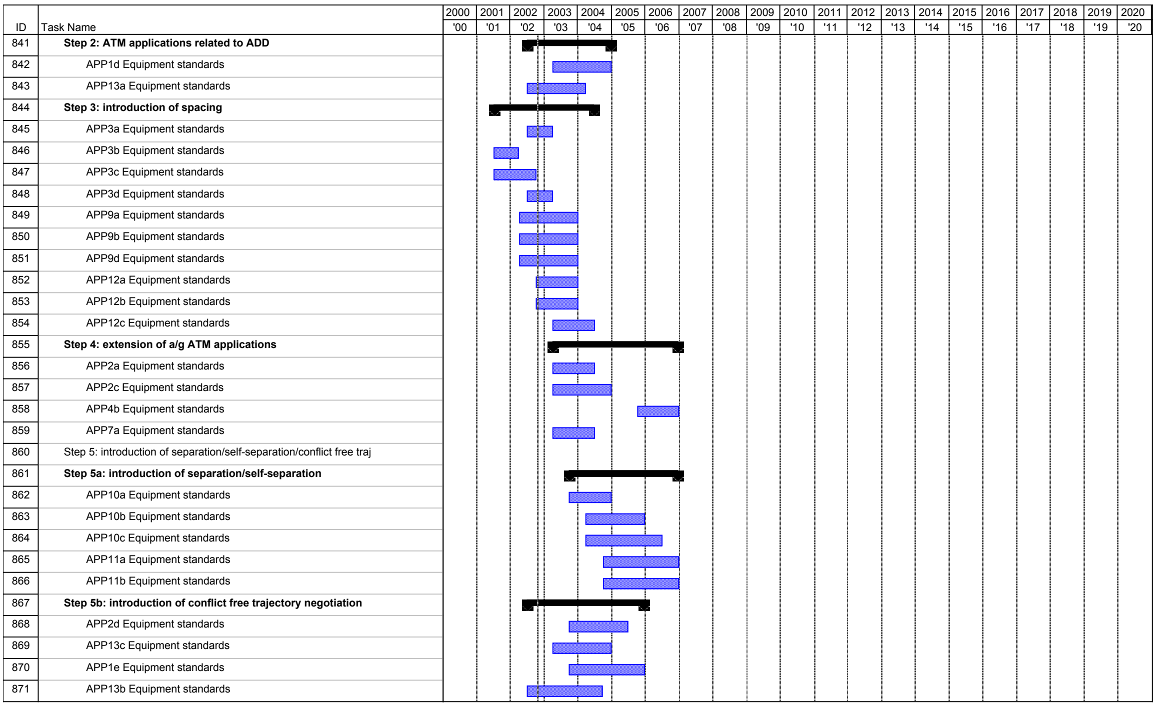

Figure 7-4: Timescales for equipment standards

7.8.3.2 For step 3, many of the equipment standards are already available. However, MOPS are required for the support of ADS-B, TIS-B and FIS-B. EUROCAE and ETSI are currently addressing the production of such equipment standards for VDL4.

7.8.3.3 For air/ground point to point communication, ICAO WG-M has approved standards for VDL4 but has yet to publish these. ETSI and EUROCAE are producing MOPS.

7.8.3.4 Standards for step 5 technologies are not yet available and the community urgently needs to start standardisation work.

7.8.4 Regulatory and airspace planning and spectrum issues

7.8.4.1 The timescales for resolution of regulatory, airspace planning and spectrum issues are shown in Figure 7-5.

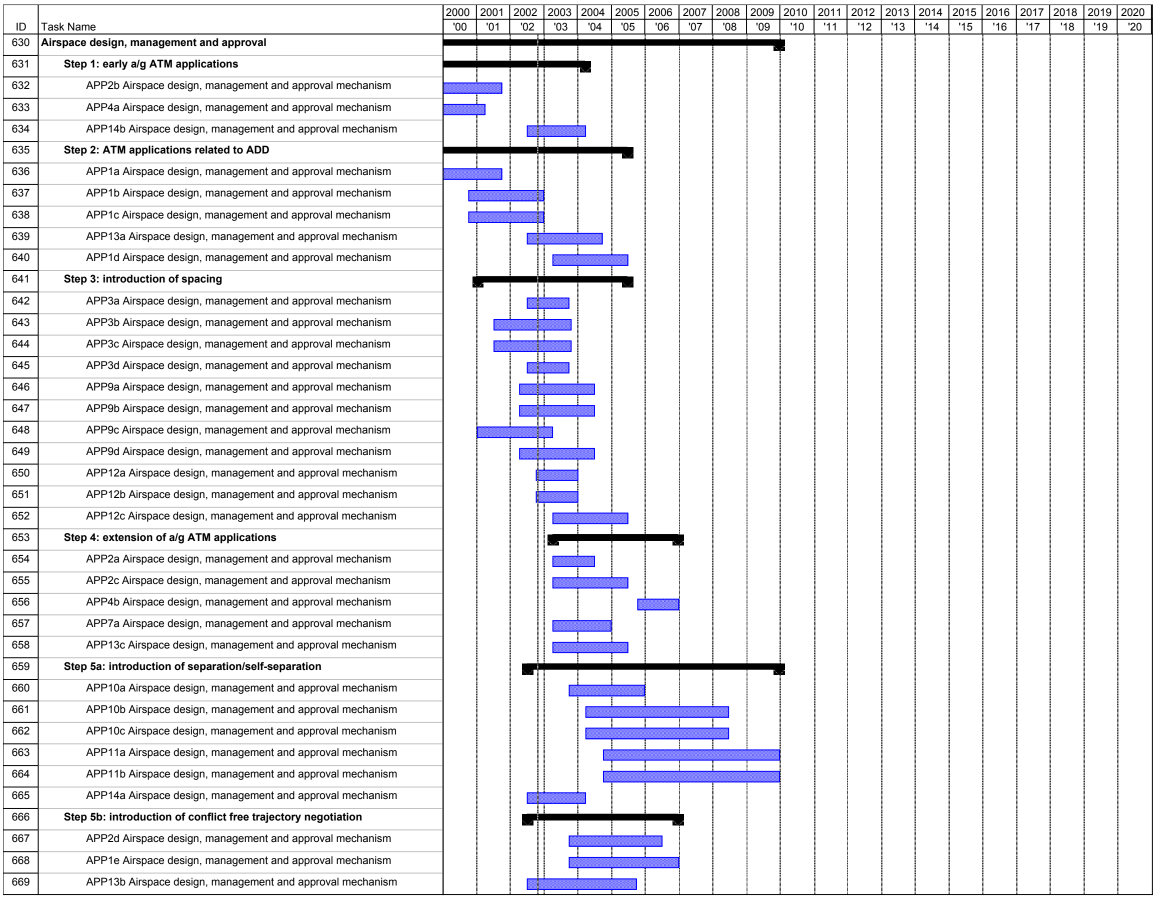

Figure 7-5: Timescales for resolution of regulatory, airspace planning and spectrum issues

7.8.4.2 The ATM applications enabled in steps 1 to 4 focus primarily on automation of the current paradigm. This involves moving parts of the current control process to the pilot and/or moving communication from voice to data. For all of the ATM applications in this early period, it is assumed that back up procedures based on current procedures are in place to provide safety assurance. Hence:

- it is only the strategic parts of the air/ground communication tasks that are moved to data;
- only spacing applications are considered.

7.8.4.3 This simplifies some of the regulatory, airspace planning and approval issues since there is not whole scale change to the ATM process. However, the first steps set the scene for a later more profound change to the ATM paradigm which will have significant implications for regulators. The early steps in the roadmap provide an opportunity to address these issues and to gain confidence in the concepts and technologies that will eventually support step 5.

7.8.4.4 Therefore the objectives for regulation in the short term are:

- to provide a time-efficient approval mechanism for the ATM applications enabled during steps 1 to 4.
- to put in place appropriate monitoring activities so as to build confidence for step 5 ATM applications
- to use the experience gained to put in place approvals mechanisms for step 5.

7.8.4.5 Putting in place an approvals mechanism will need to address issues which include:

- Monitoring and evaluation of Galileo and GPS based position information. It is recommended that a European body be set up to carry this out. The monitoring work will include reporting on GPS anomalies, liasing with Galileo requirements gathering, liasing with similar monitoring organisations elsewhere in the world.
- Monitoring developments in GPS/Galileo-inertial navigation which are predicted to provide RNP values of 0.1 Nm.
- preparing the ground for successive stages of delegation;
- putting in place requirements for certification of airborne equipment. The basic level for certification is non-interference with other systems. However, the data link technology supports increasingly more critical parts of the ATM process and, accordingly may need more rigorous certification processes.
- rationalisation of current SSR network (ie reducing multiple coverage by ground stations located in different European states) can provide potential benefits including saved costs by using 1090 ES out or VDL4 instead of relying on Mode S enhanced surveillance infrastructure. Rationalisation of the SSR infrastructure also has to potential to reduce the level of interference which has the additional benefit of improving the performance of 1090 ES.

7.9 Development of products

7.9.1 Controller working position

7.9.1.1 The current use of automation is limited by the inflexibility of many centres:

- flight data is presented on paper strips making it difficult to enter and respond to changes;
- radar displays present the minimum level of target information and are not adaptable to incorporate alerts and a greater range of flight data;
- the controller interface unable to provide an interface for digital communication.

7.9.1.2 The timescales for change are long. It is important that required changes are agreed soon and industry prototypes developed and accepted by controllers allowing new procurements to include the appropriate toolsets.

7.9.1.3 The roadmap indicates that:

- in the period up to the end of 2004, adaptation of controller suites will be required to support the air/ground ATM applications of step 1;

- in the period up to the end of 2007, progressive implementation of controller tools using ADD will be required. This will include adaptation to controller displays to indicate a range of airborne data, conflict advisories and resolutions advice. The FDP/RDP will also need to be updated to provide additional alert processing.
- also in the period up to 2007, minor display adaptations are required to support spacing ATM applications;
- from 2007 onwards, successive development of controller suites to support a greater range of air/ground communication services, ultimately supporting trajectory negotiation from around 2008 onwards.

7.9.1.4 Given that these developments occur within the lifetime of most air traffic systems it is essential that products are developed that allow straightforward upgrade of capability when it is required. At the very least, the basic CWP product will need a capability that is capable of supporting air/ground data services and ADD.

7.9.2 Ground data processing and networking

7.9.2.1 The implementation of data link technology and the ATM applications supported by the technology requires update and modification to data processing and ground networks as follows:

- implementation of a ground network supporting air/ground communications in steps 1, 5 and 5b;
- implementation of a ground network carrying surveillance related data to support:
  - ADD data to centres in step 2;
  - TIS data to aircraft in step 3.

7.9.2.2 There will also be a need for the following system modifications:

- upgrade of radar data processing systems to enable handling of:
  - fusion of data from various sources including ADS-B data
  - a greater range of aircraft data made available in step 2
  - provision of unified target data for TIS-B networks.
- implementation of flexible FDP systems capable of adapting to real time flight trajectory data.

7.9.2.3 The establishment of common standards for these networks and systems is essential to ensure the availability of capable interoperable system components.

7.9.3 Airborne infrastructure

7.9.3.1 An important barrier to the uptake of technology required to support the data link roadmap is the very high investment necessary by operators. Production of the low cost solutions to provision of technology should therefore be given high priority. This includes:

- Multimode radios to facilitate upgrade between VDL modes and non-VHF technologies considered for step 5;
- Standard HMI, CDTI and CMU fits;
- Airborne architecture suitable for VDL3, VDL4 and UAT ;
- Architecture and components to support GA.

7.10 Technology development

7.10.1 General

7.10.1.1 The study analysis has concluded that performance limitations of the early technologies place a limit on the obtainable benefits at around 2010/2011. Specifically, step 4 ATM applications may be delayed unless sufficient datalink capacity can be found. The solutions to this are:

- hasten the introduction of the technology required for step 5
- provide an interim step based on currently available technologies.

7.10.1.2 Of these, the first is preferable since it reduces the number of separate equipage events for operators.

7.10.1.3 Therefore there is an urgent need to undertake research and development on the appropriate technology for steps 4 and 5.

7.10.1.4 It is therefore recommended that:

- Research into the 'Newcom' is given a high priority
- Flight trials of VDL4 are conducted to support the finalisation of the point-to-point functionality.
- European institutions continue to monitor and support US developments in VDL3 and UAT in case these technologies are able to provide a better solution than VDL4.

7.10.1.5 A detailed technical and cost benefit assessment is conducted to support the required decisions.

7.10.1.6 Some key areas to address for step 5 data link technology are set out below.

7.10.2 Development of UAT

7.10.2.1 UAT is potentially a very capable system, which has the capacity and range to support ATM applications, but which is immature in terms of standardisation and evaluation. Trials have been carried out in the US but not yet in Europe. Clearing the DME band for the use of UAT is a much more complex issue in Europe than in the US. This is due to:

- Future requirements for an additional 180-200 DMEs to support the proposed RNP RNAV mandate [258].
- The need to co-ordinate across all 41 ECAC states.

7.10.2 However, the US has already identified a frequency (978 MHz, the lowest DME frequency that can be coordinated on an international basis) which is paired with the 108MHz VOR frequency. In general, 108 MHZ is not used due to the problems associated with the sound broadcasting services directly below it. Therefore, it is possible that the DME frequency identified for UAT could be made available on a global basis. An investigation of this frequency in Europe [147] found that whilst it was not heavily used (6 allocations) it was difficult to reassign these allocations within the DME band. This investigation did not consider the need for additional DMEs in Europe.

7.10.2.1 Nevertheless, the ongoing development of UAT should be tracked in Europe and a decision made on its eventual adoption. Assuming that UAT is a candidate for step 5 of the roadmap, a decision is required by end 2005 at the latest in order to allow equipage to start.

7.10.3 VDL3

7.10.3.1 VDL3 has not been given a role in the roadmap because:

- Although it is a promising data link – its focus for implementation is on voice which is probably not needed in Europe in the next 10 years. VDL3 does have a wide area data only configuration (3T) which may be suitable for Europe.
- The main problem seen with adoption of VDL3 in Europe is frequency congestion.

Demand for voice channels increases at 4 % a year, in US, and also in Europe. Europe will face voice channel saturation by 2015 (although see discussion in section 6.3 on possible ways to reduce the requirements for voice channels). Alternative means of providing digital voice might be provided by other step 5 candidate technologies such as 3G.

7.10.3.2 It is therefore recommended that VDL3 is kept under review as a potential means of providing voice traffic from 2015 and also as a potential wide area datalink in Step 4.

7.10.4 Future communications media

7.10.4.1 The technology assessment that no existing aviation technology was capable of supporting the high capacity and low transit delays required for conflict free trajectory negotiation. Of the future technologies considered, 3G was the most promising. The use of CDMA protocols by satellite also offer certain advantages and the combined use of satellite and terrestrial 3G protocols is of particular interest.

7.10.4.2 Other avenues should also be considered, for example the application of the STDMA protocols in sub-bands of L-band.

7.10.4.3 The Community needs to support the development of both systems. The dual use of a datalink for safety and non-safety applications causes certain certification and institutional issues. Research is required to resolve these issues. In particular firewall and security issues should be considered.

7.11 Other issues

7.11.1 The ATM applications discussed in this project can not happen in isolation, they require improvements to the navigation capability of the fleet and need to be sympathetic to the increasing requirements for ATS voice and AOC data communications.

7.11.2 Particular developments of interest are:

- 8.33 kHz expansion programme. When will a new technology be required to support ATS voice? Or will re-sectorisation occur early enough to prevent the need for a new technology?
- Collaborative Decision Making and other AOC developments are increasing the amount of information sharing within the industry. Will these developments lead to a large increase in the amount of air-ground data?
- Europe is considering the introduction of RNP RNAV or 4D RNAV. What are the datalink requirements for this evolving capability?

7.11.3 During the study working assumptions have been used to account for these factors. Detailed studies are however required to ensure that these development dovetail with the datalink roadmap in the 2012-2015 timeframe.

8 Summary of roadmap actions

Action and objectives	Consequences if not carried out	Complete by	Stakeholder
Set up coordinating body to rationalise sectorisation in Europe: optimise use of current capacity optimise sectorisation as further capacity is provided via implementation of ATM applications liaise with spectrum planning activities, seeking opportunities to reduce requirement for voice channels	Failure to deliver capacity related benefits Rapid increase in number of sectors required to provide airspace capacity leading to: • failure to deliver benefits resulting from reduced user charges • escalating requirement for additional VHF spectrum to accommodate new sectors	Ongoing task	Single Sky Unit Eurocontrol
Coordination of spectrum allocations: provide sufficient spectrum for early use of VDL2 and maybe VDL4 (including considering spectrum allocation in the nav band for VDL4 surveillance applications) plan for provision of spectrum for further use of VDL2 and maybe VDL4 taking account of traffic growth and additional applications investigate spectrum allocation for UAT (dependent on eventual adoption of UAT) protect aeronautical use of L-band for satcom	Use of VDL2 and maybe VDL4 in steps 1 to 4 is critically dependent on provision of spectrum – consequence of not providing spectrum is to delay ATM application roadmap (specifically step 4, but also the expansion of ATM applications provided by step 1)	Ongoing action with a number of milestones: 2003 – secure VHF allocation for early use of VDL2 (believed to be complete) 2004 – taking account of the listed safety issues , secure VHF allocation for early use of VDL4 2005 – channel plan for extended use of VDL2 and maybe VDL4 2006 – resolve spectrum allocation for UAT	Eurocontrol
Establish and maintain European business case: provide operators with clear visibility of progress against targets maintain cost database	Successful delivery of the roadmap requires Europe wide action – failure to provide an overall business case will lead to removal of the incentive to equip and hence failure to deliver overall benefits	Ongoing task	Eurocontrol PRC

Action and objectives	Consequences if not carried out	Complete by	Stakeholder
link to evolution of user charges			
Stimulate equipage consider need for mandate for Mode S ES consider mechanism to encourage equipage of technology for steps 1 to 4, including differential user charges prepare groundwork for mandate for step 5 technology	Unless proactive steps are taken to encourage equipage, the industry is unlikely to equip at the rate necessary to deliver the benefits from steps 1 to 4.		Single Sky Unit and States
Implement pilot projects provide earliest possible operational implementation of key ATM applications determine appropriate regions for early implementation coordinate stakeholders contributing to each pilot project	Late implementation of ATM applications in core region Failure to deliver benefits in a timely fashion	Step 2 complete by 2006 Step 3 complete by 2007 Step 4 complete by 2008 Step 5a (separation) complete by 2010 Step 5a (self-separation) complete by 2012 Step 5b complete by 2008	Appropriate ANSPs and operators based in selected regions European Commission
Validation of technology performance confirm performance for data link technologies determine spectrum requirements of VDL2 and VDL4 confirm performance of broadcast technology address specific performance issues associated with each technology	Delay to adoption of technologies by stakeholders Potential wrong direction for early adopters	2003 –VDL2/VDL4 performance issues 2004 – approach to provision of a/g service for step 4 2005 – evaluation of step 5 technologies	Eurocontrol
Establish ATM application standards MASPs for ADS-B applications standards for step 5	Failure to provide standards prevents completion of operational concepts and equipment standards	Step 2 complete by 2003 Step 3 complete by 2004 Step 4 complete by 2004	EUROCAE and ICAO

Action and objectives	Consequences if not carried out	Complete by	Stakeholder
		Step 5a complete by 2006 (separation), 2007 (self-separation) Step 5b complete by 2005	
Establish equipment standards complete MOPS for ADS-B applications prepare equipment standards for step 5	Delay to roadmap	Step 2 complete by 2005 Step 3 complete by 2004 Step 4 complete by 2005 Step 5a complete by 2006 (separation), 2007 (self-separation) Step 5b complete by 2006	ICAO, ETSI, EUROCAE
Coordinate regulatory and airspace planning issues monitor activities including GPS performance put in place procedures for certification of new ATM applications rationalise SSR network	The early days of the roadmap start the process of changing the control paradigm – this includes: • use of data link for routine communication • use of airborne surveillance picture to carry out spacing activities These will be accompanied by the need for new approvals process, the absence of which will delay the roadmap.	Approvals for spacing applications by end 2004 Approvals for separation applications by end 2008	Eurocontrol SRC and States
Promote standardised approach to provision of ground infrastructure provide standards for CWPs accommodating electronic flight data, displays of ADD, controller decision tools, air/ground digital exchanges provide standards for FDP and RDP stimulate production of industry products	Major system upgrades are required to support the roadmap. Failure to provide standard solutions will increase costs and further delay implementation of the roadmap ATM applications	Major upgrades for steps 1 to 4 required starting in 2004	Industry and ANSPs

Action and objectives	Consequences if not carried out	Complete by	Stakeholder
Promote standardised approach to provision of airborne architecture: software radios common CDTI and CMU components	Minimising the cost of airborne infrastructure is the key cost issue identified by the study – any airborne cost is a disincentive to equip	Step 1: required now Step 2: required now Step 3: by end 2003 Step 4: by end 2005 Step 5 by end 2006	Industry and EUROCAE
RTD actions to identify and evaluate step 5 technology early validation of new technology required to support timely imposition of mandate evaluation of UAT/VDL3	Step 5 requires technology decision for placing a mandate in 2007 – failure to provide this will delay step 5	Decision on next technology by end 2007	Eurocontrol and European Commission

9 Acronyms

1090 ES	1090 Extended Squitter
3G	Third Generation
ACARS	Aircraft Communications, Addressing and Reporting System
ACL	ATC Clearance
ACM	ATC Communications Management
ADD	Air Derived Data
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance - Broadcast
ADS-C	Automatic Dependent Surveillance – Contract
Aero-GAN	Aeronautical - Global Area Network
AIC	Aeronautical Information Circular
AMAN	Arrivals Manager
AMCP	Aeronautical Mobile Communications Panel
AMSS	Aeronautical Mobile Satellite Service
ANSP	Air Navigation Service Provider
AOC	ACARS over AVLC
AOC	Aircraft Operational Control
ASAS	Airborne Separation Assurance System
AT	Air Transport
ATC	Air Traffic Control
ATIS	Automated Terminal Information Service
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
ATS	Air Traffic Services
ATSAW	Airborne Traffic Situational Awareness
AVLC	Aviation Link Control
AVPAC	Aviation Packet Radio
CAP	Controller Access to Parameters
CBA	Cost Benefit Analysis

CDMA	Code Division Multiple Access
CDTI	Cockpit Display of Traffic Information
CEAP	Central European Air Traffic Service Provider
CFMU	Central Flow Management Unit
CMU	Communications Management Unit
CPDLC	Controller Pilot Data Link Communications
CWP	Controller Work Position
DAP	Downlink of Aircraft Parameters
DCDU	Datalink Control and Display Unit
DLIC	Datalink Initiation Capability
DMAN	Departure Manager
D-OTIS	Datalink – Operational Terminal Information Service
D-RVR	Datalink – Runway Visual Range
D-SIGMET	Datalink Significant Meteorological Report
DYNAV	Dynamic Route Availability
ECAC	European Civil Aviation Conference
E-S&A	Enhanced – See and Avoid
E-TIBA	Enhanced – Traffic Information Broadcast
ETSI	European Telecommunications Standards Institute
EVA	Enhanced Visual Acquisition
FAA	Federal Aviation Authority
FANS	Future Air Navigation Service
FDP	Flight Data Processor
FLIPCY	Flight Plan Consistency
FLPINT	Flight Plan Intent
FMC	Flight Management Computer
FMS	Flight Management System
GA	General Aviation
GPS	Global Positioning System
HFDL	High Frequency Data Link
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation

IMC	Instrument Meteorological Conditions
ITC	In Trail Climb
ITD	In Trail Descent
JURG	Joint IATA / AES CNS/ATM User Requirements Group
MASPS	Minimum Aviation System Performance Standards
METAR	Meteorological Report
MFF	Mediterranean Free Flight
Mode S EHS	Mode S Enhanced Surveillance
MOPS	Minimum Operational Performance Specifications
MTCD	Medium Term Conflict Detection
NGSS	Next Generation Satellite Service
NPV	Net Present Value
NUP	NEAN Update Project
OFIS	Operational Flight Information Service
OI	Operational Improvement
RDP	Radar Data Processor
RNAV	Area Navigation
SARPS	Standards and Recommended Practices
SDLS	Satellite Data Link Service
SIGMET	Significant Meteorological Report
SNOWTAM	NOTAM/Snow Alert
SPF	Strategic Performance Framework
SSR	Secondary Surveillance Radar
STARS	Standard Arrivals
TCAS	Traffic Alert and Collision Avoidance System
TIS-B	Traffic Information Service – Broadcast
UAT	Universal Access Transponder
UMTS	Universal Mobile Telephony Service
US	United States
VDL	VHF Digital Link
VDL2	VDL Mode 2
VDL3	VDL Mode 3

VDL4	VDL Mode 4
VDR	VHF Datalink Radio
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
WG	Working Group