Data Link Roadmap – Summary

Background

This document summarises the results of a study[1] for the European Commission to develop a roadmap for the implementation of data link services supporting air traffic management (ATM) applications in Europe. The study carried out 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.

Phase 1 of the study established a list of ATM applications that would be 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. Stakeholders reviewed the list of ATM applications extensively and agreement was reached as to the priority and timescales required to match the demand for capacity for each ATM application. This list was cross checked[2] against, and found to be consistent with, other initiatives such as the work on a first package of ADS/B applications.

Phase 2 assessed the candidate data link technologies, taking account of the ability to meet the technical requirements of the ATM applications, technology maturity and cost.

A public consultation process was carried out on the results of Phase 1, and input received from a wide range of Stakeholders. A further public consultation was carried out during January/February 2003 and a Stakeholder Workshop held on 21 February 2003.

This summary document presents the main conclusions of the work undertaken[3]. The annexes to this report summarise additional technical detail[4].

Consensus forming and the way ahead

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.

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.

ATM Application Roadmap

The maintenance or enhancement of safety is central to the provision of ATM, and the study team has ensured that the identified ATM applications would assist in maintaining or increasing safety levels. A major driver to the identification of the ATM applications relates to the provision of additional capacity. Without additional capacity, the cost of delays will lead to rapidly escalating costs for the industry and failure to accommodate demand will lead to an unacceptable situation for the aviation community and the European travelling public. Finally another important driver is the possibility to reduce the cost of the ATM provision through a move from a context of operations where the number of sectors keeps increasing to a context of stabilisation then reduction of the number of sectors.

The most urgent area for capacity enhancement is terminal airspace, where capacity restrictions already result in considerable service disruption. The study concluded that the main capacity enhancing step is the use of trajectory planning by ground systems, requiring the setting of arrival times into terminal airspace.

In spite of relief gained from the recent introduction of RVSM, it is also important to keep making continuous progress on en-route capacity provision, and the study results indicate that implementation of spacing and separation ATM applications based on ADS-B in En-Route airspace is a first means to achieve capacity and requires the availability of applications based on effective delegation of separation responsibility to the pilot.

The objective is to facilitate growth while keeping the cost of the infrastructure, and particularly the number of sectors, at the lowest possible levels. As traffic grows, this would lead to a significant reduction in ATM costs per flight and probably reduced flight times and fuel burn.

For the airport region, the study recommended the use of airborne spacing for arrivals in order to achieve near to the minimum allowed separation and the use of ATSAW and aircraft derived data to improve the efficiency of airport operations, to support operations under IMC conditions and to provide runway and final approach occupancy awareness. For oceanic and remote regions, the study identified applications based on ADS-B to support surveillance and airborne separation.

Overall benefits are delivered in 5 steps:

- **Step 1: Early air/ground ATM applications**, with a target for widespread operational use by **2006**.

- **Step 2: ATM applications related to downlink of air-derived data**, with a target for widespread operational use by **2008**.

- **Step 3: Introduction of spacing**, with a target for widespread operational use by **2010**.

- **Step 4: Extension of air/ground ATM applications**, with a target for widespread operational use by **2009/10**.

- **Step 5:** Consists of: **Step 5a: Introduction of separation and self-separation**; and **Step 5b: Conflict free trajectory negotiation**. These have a target for widespread operational use from **2013** onwards.

Note that "widespread operational use" is defined in the study, by analogy with previous cost benefit studies on new technologies, including Mode S Enhanced Surveillance and LINK 2000+, as the date when an optimum of about 75% of aircraft are equipped (unless the application requires full equipage) with the necessary technology and the ground systems support the ATM application[5]. The timescales quoted above are based on needs for capacity and do not take account of industry implementation plans or technical constraints.

Stakeholders reviewed the ATM application roadmap during the first consultation phase. The key issues raised were:

- The timescales are unlikely to be achievable given current industry implementation plans, mainly based on institutional constraints and practice rather than on actual technical constraints.

- There is a need for further validation of the benefits provided by each step.

- There is a need to agree on a long-term vision for capacity provision, balancing the approaches used in steps 5a and 5b.

Technology assessment

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[6].

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.

The study analysed a number of scenarios combining the data link technologies[6] .All of the scenarios considered provide benefit[8] 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[9].

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

- The availability and capability of technologies[10].
- 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 [11].
- 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 EHS) in core Europe, building on the current mandate for Mode S Elementary Surveillance[12].
- Investment by ARINC/SITA in VDL2 ground networks for AOC applications[13].
- Investment by Airbus in solutions to support a data link technology route based on VDL2, Mode S EHS and 1090 ES[13].
- Emerging plans for a VHF digital link Mode 4 (VDL4) AOC network[15].
- Investments made by EU and project partners in EU sponsored test and trials projects of VDL4 for ADS-B ATM applications[16].
- Plans for implementation of VDL4 based ATS networks in Sweden and Russia[17].

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[18] 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.
    - 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 single 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[19]:

    - 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.

Possible strategies for data link implementation

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

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"[20].
- 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.

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.

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[22].

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

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[24].

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:

- 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[23]. However, this reason cannot be accepted, based on the necessity to meet demand.

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.

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

The study 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. Moreover the shortage of VHF spectrum may necessitate optimisation of the usage of VHF spectrum prior to the introduction of a new link and/or the introduction of an alternative broadcast data link technology to support Step 5a outside the VHF spectrum.

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

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.

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.

The need to accelerate roadmap timescales to provide sufficient capacity to meet demand

Timescales established in Phase 1 were based on needs for 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. The table below illustrates these timescales 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** (based on perception by SITA of market reaction assuming no incentive for early equipage.) (75% equipage)
Step 2: ATM applications related to downlink of air-derived data	**2008** (75% equipage)	**2006** (Airbus) (>75% of equipage)
Step 3: introduction of spacing	**2010** (75% equipage)	EVA only – **2007** (Airbus) Final approach spacing[25] + EVA– **2008** (Airbus) Other spacing[25] – **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+**	Oceanic and remote –**2012** (Airbus) Terminal an en-route[25] – **2018** (Airbus) Sole means surveillance[25] –**2017 – 2019** (Airbus)

	(75% equipage)	(All dates – start of equipage)
Step 5b: conflict free trajectory negotiation.	**2013+** (75% equipage)	**2011** (Airbus) (start of equipage)

With the exception of step 2, these timescales lag significantly behind those established in Phase 1. The study has shown that the timescales based on current industry implementation plans will probably not meet the increased traffic demand during the next 15 years. 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.

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 5a. The Community should therefore take steps to ensure a more rapid implementation of data link technology.

Actions for community to support decision making

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

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.

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.

Urgent actions

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.

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.

Other actions

Completion of the urgent actions will support the decision process for steps 1, 2 and 3 of the roadmap. Thereafter, other actions must be carried out to support the early steps of the roadmap and to support decisions for later steps.

The actions identified by the study are summarised in Annex E of the current document. The key actions are:

- **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.
- **Rationalisation of VHF spectrum**. The VHF spectrum reserved for aviation use is in desperately short supply. Increases in traffic create further demands for voice channels. In addition, the transfer from voice to data provides additional requirements for channels,

during a transition period, 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 years of the roadmap depends on the transfer of services to data channels within the VHF spectrum. A key output of this action is to provide frequency assignments for the data link technologies supporting the roadmap.

Other necessary actions include:

- Establish and maintain a European business and safety case to provide operators with clear visibility of progress against targets. A detailed technical and cost benefit assessment should be conducted in consultation with the FAA.
- Determine measures to stimulate airborne equipage and deployment of ground infrastructure from ANSPs including use of mandates and incentives for early equipage and differential user charges.
- Implement pilot projects so as to provide the earliest possible operational implementation of key ATM applications.
- Establish appropriate ATM Application and equipment standards.
- Co-ordinate regulatory and airspace planning issues.
- Promote a standardised approach for the provision of airborne and ground infrastructure.
- Carry out RTD actions to identify and evaluate technologies for Steps 4 and 5. This should include monitoring and supporting US developments in VDL3 and UAT but also ensuring that the US do not close the door to 8.33 as an effective means of creating spectrum for voice communication. Research into new data link technology should be given high priority including both terrestrial and satellite technologies.
- Community to use its teeth under Single European Sky legislation but already today as part of Eurocontrol and ICAO to ensure that decisions are taken in due time.

Acronyms

ADS-B	Automatic Dependent Surveillance - Broadcast
ATM	Air Traffic Management
AOC	Aircraft Operational Communication
1090 ES	Mode S 1090 MHz Extended Squitter
IAA	Irish Aviation Authority
IATA	International Air Transport Association
Mode S EHS	Mode S Enhanced Surveillance
NATS	UK National Air Traffic Services
RTD	Research and Technological Development
STATFOR	Eurocontrol Air Traffic Statistics and Forecast Service
UAT	Universal Access Transceiver
VDL2	VHF Data Link Mode 2

VDL3	VHF Data Link Mode 3
VDL4	VHF Data Link Mode 4
VHF	Very High Frequency

Notes

1. The study was led by Helios Technology Ltd and supported by Sofréavia, Integra, International Air Transport Association (IATA), Airbus and the University of Leiden. This core team was supported by a "Peer Review Group" consisting of UK National Air Traffic Services (NATS), Irish Aviation Authority (IAA), Swedavia, Mitre and Astrium. Eurocontrol provided review and technical assistance.

2. See P167D1030 section 6.2.2.

3. The results of the study are contained in the following reports:

   - "**Application Assessment**", P167D1030 version 2.0, 30 October 2002. This 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 presents the results of a summary of requirements for non-ATS applications.

   - "**Technology Assessment**", P167D2020 version 5.0, 28 February 2003. This presents the results of the assessment of data link technologies carried out in Phase 2 of the study. The document is subdivided as follows:

     a. The main body of the report summarises the technology assessment, scenario analysis and technology selection.
     b. The annexes of the report describe each of the technologies considered in the study as well as the overall network architecture and the cost assessment.

   - "**Data link Roadmap**", P167D2010 version 3.0, 28 February 2003. This provides the overall conclusions of the study and presents the data link roadmap and associated community actions.

   - "**References**", P167D3030 version 3.0, 28 February 2003. This sets out the references used in the study.

   - "**Phase 2: Public Consultation**", P167D016, version 1.0, 28 February 2003. The records the results of the second public consultation between January and February 2003.

4. The annexes contain:

   - Annex A: a list of the ATM applications identified in the study
   - Annex B: the ATM application roadmap and associated timescales and data link services
   - Annex C: the results of the technology assessment
   - Annex D: A summary of community measures.

5. The ATM applications identified in the study and their allocation to the steps in the Roadmap are summarised in Annexes A and B.

6. The data link technologies considered and conclusions reached on each technology are summarised in Annex C.

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

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

9. A discussion of the community actions required to deliver the benefits is summarised later in the summary document, in Annex D and in Section 7 of P167D2010.

10. 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.

11. The decisions and recommendations that the study team were made aware of were:

    - a decision in the US to adopt 1090 ES as the first ADS-B link;
    - recommendations by IATA and the AEA 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.

12. The 'three states plan' (signed in 2002) identifies the 31st March 2005 as the Mode S EHS 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.

13. Current implementation plans for VDL2 presented to the study team by ARINC and SITA are summarised in P1672020 Section F.5.

14. Details of the equipage steps and timescales envisaged by Airbus are contained in P167D2010 paragraphs 6.3.12 to 6.3.13.

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

16. A summary of trials activity involving VDL4 is contained in P167D2020 Section J.

17. VDL4 implementation plans are described in P167D2020 Section J.3.3.

18. The issues are summarised in P167D2010 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.

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

20. ADS-B "out" supports the broadcast of position and intent data from an aircraft. This data could be received by ground stations to enable air-ground surveillance applications. ADS-B "in" supports the receipt of ADS-B data by an aircraft and enables air-air applications.

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

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

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

24. Eurocontrol and SITA views on limitations of VDL2 in step 4: see P167D016 Annex comments 47 and 164.

25. Following discussion recorded during final editing of this document: IATA: Does AIRBUS feel strongly about these dates? I suppose that if traffic dictates to speed up the full process, AIRBUS would not drag its feet because it is AIRBUS policy to deliver in time to meet demand. I suppose AIRBUS concurs that if we can change the paradigm and adopt a more business oriented culture, we can deliver the changes faster and get them implemented in time thanks to appropriate mandates. Moreover everybody agreed at the workshop that on technical grounds it was possible to achieve the required timescales and only the slow modus operandum of ICAO and states prevented from doing things on time. An expectation is that the Community will use its teeth to put things in order. Airbus response: The IATA note is correct except as regards spacing and separation (steps 3 & 5a), where the industry does not have the technology to allow safe routine airline operations – hence the dates. After all, we don't want pilots to be flying around with their attention tunnel-riveted on a display, wondering when the aircraft they are spacing or separating from is going to start manoeuvring. They need their attention to go in the existing directions, as well, if they are to operate safely.

Supporting information

A Description of ATM applications

#	ATM application	Description
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 3 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.
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. Provision of surveillance coverage by a similar means in the airport environment is covered by APP13a. This ATM application is not judged to be relevant to remote regions where there is unlikely to be extensive radar coverage.
APP1e	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.
APP2a	Pilot preferences data link	Downlink of a pilot's preferred routing.
APP2b	Strategic controller/pilot messages	This includes downstream clearances for oceanic, information on Standard Arrivals (STARS), pre-departure clearances (DCL) at airports.
APP2c	Support for increased automation	This provides a full range of data link services which provide increased automation.
APP2d	Trajectory negotiation	This provides services supporting 4D trajectory negotiation, conflict free trajectories.
APP3a	Enhanced visual acquisition (EVA) in remote and oceanic airspace	Provides enhanced visual acquisition (EVA) in remote and oceanic airspace
APP3b	Enhanced visual acquisition (EVA) in terminal airspace	Provides enhanced visual acquisition (EVA) in terminal airspace
APP3c	Enhanced visual approaches	Provides 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).
APP4a	Provision of D-OTIS (ATIS, METAR) and D-RVR	This ATM application concerns automation of services that are currently delivered by voice.
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.

#	ATM application	Description
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.
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)[1]. 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[2].
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 [2].
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.
APP11b	Autonomous operations in FFAS	This is expected to apply initially in remote or transitional en-route airspace and then later to core airspace.
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.
APP13a	Fusion of current terminal and/or surface radar with other surveillance means	This provides enhanced surveillance accuracy for Center – TRACON Automation System (CTAS) and other terminal automation tools.
APP13b	ATC surveillance using ADS-B at airports.	This enables application of pseudo radar separation standards at airports without radar coverage
APP13c	Routing	This provides routing information such as taxi clearances to aircraft on the airport surface.

[1] AEA/IATA ATM-CNS Joint User Requirements Group (JURG) ADS Fast Track Initiative JAFTI, Version 1.2, May 2002.
[2] An analysis of the costs and benefits of ADS based on operational case studies - Results of Stage 1 ADS Programme CBA, Edition 0.4, Eurocontrol September 2001.

#	ATM application	Description
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.
APP14b	ATS in oceanic/remote areas	This includes controller/pilot data link communications (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. In the analysis carried out in this document, it is assumed that the initial implementation of this ATM application will be supported by the FANS1/A equipage.

B Summary of ATM applications

ATM applications	Benefits
Step 1: early a/g ATM applications	
Strategic controller/pilot messages including downstream clearances for oceanic, information on Standard Arrivals (STARS), and strategic clearances using CPDLC D-OTIS (automatic terminal information service (ATIS), Meteorological Report (METAR) and D-RVR ATS in oceanic/remote areas, including CPDLC services and surveillance via ADS-contract (ADS-C).	Terminal and en-route capacity benefits of typically 11%[1] 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
Step 2: ATM applications related to downlink of air-derived data	
Enhanced surveillance in terminal and en route airspace, limited additional information being displayed to the controller. Focuses on provision of controller access parameters (CAPs) Enhanced surveillance in terminal and en-route airspace providing a wider range of DAPs. Enhanced surveillance accuracy for automation tools in terminal and en-route airspace.	Terminal and en-route capacity benefits of typically 27%[2]. Safety benefits arising from provision of more precise information making it possible to enhance tracking and safety net tools. Improvement of flight efficiency by allowing for more anticipation in traffic planning. Validation of the use of DAP on the ground Support of other ATM applications (e.g. Arrivals Manager (AMAN), Departure Manager (DMAN), MTCD, Surface Management) that are improved using additional aircraft data.
Fusion of current radar and ADS-B surveillance in terminal and en-route airspace to achieve multiple coverage when radar is mixed with ADS-B. Fusion of current terminal and/or surface radar with other surveillance means supporting terminal automation tools.	Saving of ground infrastructure costs through the use of ADS-B technology rather than secondary surveillance radar.

[1] LINK 2000+ Programme Master Plan, Version 0.94, Eurocontrol, July 2001.
[2] Application Assessment Document, P167D1030 version 2.0, 30 October 2002.

ATM applications	Benefits
Step 3: introduction of spacing	
Airborne spacing in en-route and terminal airspace. Crossing and passing in en route airspace. Final approach spacing. Departure spacing.	Terminal and en-route capacity benefits of typically 9%[1] Enabling benefits preparing for Step 5a.
Enhanced visual acquisition (EVA) in remote and oceanic airspace EVA in terminal airspace Enhanced visual approaches Traffic situational awareness in core and transitional en-route airspace Surface enhanced visual acquisition Runway and final approach occupancy awareness Enhanced IMC airport surface operations.	Positive identification of traffic, reducing mis-identification of aircraft and earlier anticipation of collision risks Better establishment of visual contact and positive identification of aircraft Reduced time to establish visual contact to other aircraft Improved crew capability to assess the distance to a preceding aircraft Reduced probability of a go-around for parallel approaches Repeated positive identification of the target in high traffic density conditions. Capacity enhancement under marginal VMC conditions in terminal airspace.
Step 4: extension of a/g ATM applications	
Pilot preferences data link Increased automation, including strategic collaborative flight plan exchanges relying on data link services such as FLIPCY and DYNAV Full range of uplink information services, including automatic Operation Flight Information Service (OFIS). Provision of information on route availability (DYNAV). Routing, including taxi clearances to aircraft on the airport surface.	Terminal and en-route capacity benefits of typically 8% [1] 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.
Step 5a: introduction of separation, self-separation	
Airborne separation in oceanic and remote airspace. Airborne separation in en-route and terminal airspace. Final approach separation. Cluster control in ATC managed airspace. Autonomous operations in FFAS.	Considerable step in capacity: separation: 39%, self-separation (50%).

[1] Application Assessment Document, P167D1030 version 2.0, 30 October 2002

ATM applications	Benefits
Air traffic control (ATC) surveillance using ADS-B in terminal and en-route airspace. Basic surveillance infrastructure via ADS-B in remote regions.	Cost savings through use of alternative means to eg radar
Step 5b: conflict free trajectory negotiation	
Trajectory negotiation including strategic ATM exchanges such as tactical collaborative flight plan exchanges relying on COTRAC data link services.	Capacity increase through provision of conflict-free trajectory planning. Enhanced flight efficiency through provision of more optimum trajectories.

C.1 Data link technologies considered in the study

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	✓				

C.2 Assessment of data link technologies supporting point to point services

Technology	Points of Interest / Role in Datalink Roadmap
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.
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.

Technology	Points of Interest / Role in Datalink Roadmap
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.
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.

Technology	Points of Interest / Role in Datalink Roadmap
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
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.

C.3 Assessment of data link technologies supporting broadcast services

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.
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.

Technology	Points of Interest / Role in Datalink Roadmap
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.

E Summary of Community 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 link to evolution of user charges	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
Stimulate equipage consider need for mandate for Mode S EHS 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	Late implementation of ATM applications in core	Step 2 complete by 2006	Appropriate ANSPs

Action and objectives	Consequences if not carried out	Complete by	Stakeholder
provide earliest possible operational implementation of key ATM applications determine appropriate regions for early implementation coordinate stakeholders contributing to each pilot project	region Failure to deliver benefits in a timely fashion	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	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 Step 5a complete by 2006 (separation), 2007 (self-separation) Step 5b complete by 2005	EUROCAE and ICAO
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	Approvals for spacing applications by end 2004 Approvals for separation applications by end 2008	Eurocontrol SRC and States

Action and objectives	Consequences if not carried out	Complete by	Stakeholder
	These will be accompanied by the need for new approvals process, the absence of which will delay the roadmap.		
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
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