Roadmap for the implementation of Data Link Services in European Air Traffic Management (ATM):

Assessment Framework

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Document Control

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1 Assessment Framework Overview

1.1 Purpose of this document

1.1 This document has been produced during Phase 1 of a study for the European Commission to develop a roadmap for the implementation of Data Link Services supporting air traffic management (ATM) in Europe. The work has been carried out under contract B2001/B2-7020B/S12.330694.

1.2 The purpose of this document is:

- To describe the detailed technical requirements for the ATM Applications identified in Phase 1[1].
- To provide a framework for the technical assessment of data link technologies to be performed during Phase 2.

1.1.1 During Phase 2 a clear data link roadmap, including an implementation scenario for Data Link Applications together with recommendations for the most suitable technologies, will be developed. This will include justification from technical, financial and industrial perspectives.

1.2 Overview

1.2.1 During Phase 1 a number of 'ATM Applications' were identified and analysed to generate an 'Application Roadmap'. This roadmap identifies coherent groups of Data Link Applications that support safety, capacity and efficiency enhancements. Further analysis has been conducted to derive the underlying technical requirements these applications place on the selected technologies. This further analysis is presented in Section 2.

1.2.2 The remainder of the document develops the methodologies required to select the identified technologies to form a coherent data link roadmap. This set of methodologies is referred to as the assessment framework.

1.2.3 The assessment framework is provided to support two work packages of Phase 2:

- WP2100: Technology Assessment: In this work package, each candidate data link technology will be assessed individually from a technical, financial and industrial perspective. In addition, a technical framework allowing comparison between technical requirements imposed by selected ATM Applications and technical requirements provided by data link technologies will be developed. This technical comparison framework is to be used in WP2210 to determine which candidate data link technology, or combined use of data link technologies, can best meet operational requirements.
- WP2210: Technology Selection: This work package is central to the success of the project. Using the technical comparison framework prepared in WP2100, it aims at determining which end-to-end communication architectures including one or several data link technologies, but also ground architecture and airborne components, can best meet technical requirements

[1] See 'Roadmap for the implementation of Data Link Services in European Air Traffic Management (ATM): Application Assessment, P167D1030, 12 June 2002 for a list of identified ATM Applications.

derived from operational needs. This allows a first technology selection from a pure technical point of view. Each retained technical option is then cost assessed so as to provide the overall cost. The impact on European Industry is also assessed for each retained technical option.

1.2.4 The study will consider the following list of candidate data link technologies:

- VDL Mode 2
- AMSS
- HFDL
- VDL Mode 3
- VDL Mode 4
- UAT
- 1090 extended squitter (ES)
- Mode S elementary and enhanced surveillance with data link as an option
- NGSS
- Gatelink
- SDLS
- 3G/UMTS (CDMA Wideband)
- Boeing CBS

1.2.5 In addition, general surveys will also be conducted on:

- Commercial communications technologies
- Military data links

1.2.6 The purpose of these general surveys is to determine if additional community actions are required to promote the use of specific communications technologies for Air Traffic Management.

1.3 Document structure

1.3.1 The remainder of this document consists of the following sections:

- Section 2 contains the detailed technical requirements.
- Section 3 describes the assessment framework.
- Section 4 describes the methodology for technical assessment.
- Section 5 describes the methodology for cost assessment.
- Section 6 describes the methodology for industrial assessment.

1.3.2 The document is completed by the following annexes:

- Annex A contains the template for the technical assessment
- Annex B contains the template for cost assessment.

2 Detailed Technical Requirements

2.1 Introduction

2.1.1 This section presents the detailed technical requirements for communication derived from the operational message exchange characteristics of the selected ATM Applications. The detailed technical requirements characterise the categories of Data Link Applications that are necessary to support the set of ATM Applications selected in Phase 1.

2.1.2 The method follows the standard decomposition of ATM Applications into Data Link Services and Data Link Applications used in the specification of communication system requirements and is equivalent to, for example, the definitions used in ODIAC [REF05].

2.1.3 The method for obtaining the detailed technical requirements is illustrated in Figure 1.

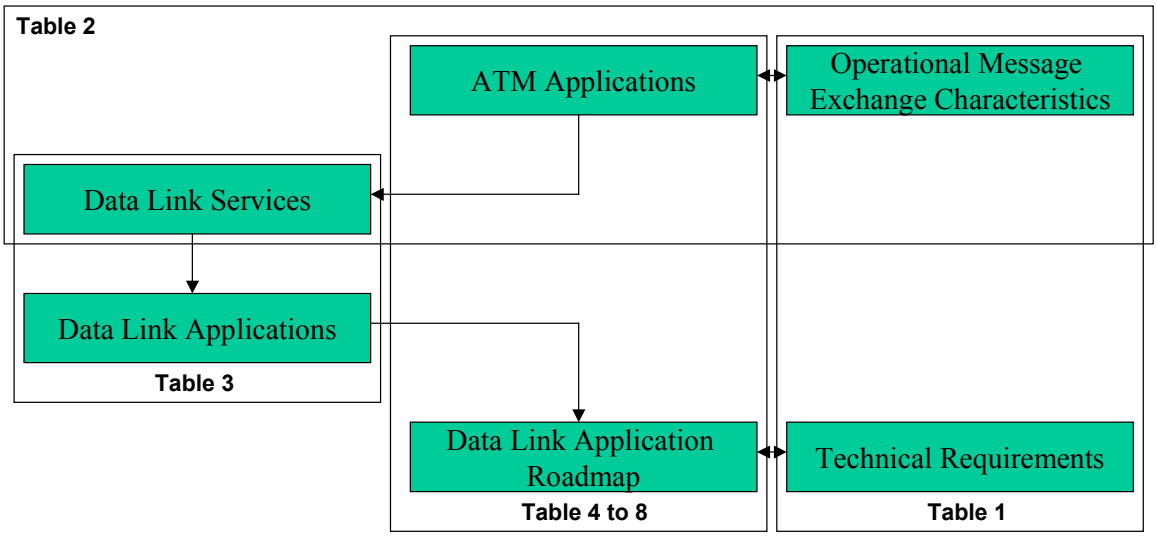


Figure 1: Method

2.1.4 The term “ATM Application” is used to represent a change to the way in which air traffic management is carried out. ATM Applications and associated timescales for implementation were identified in Phase 1 and placed on an ATM Application Roadmap. This is described in study document P167D1030.

2.1.5 ATM Applications require the exchange of operational messages. For each ATM Application, a set of Operational Message Exchange Characteristics has been identified. Table 1 defines the characteristics used and the range of possible operational values. The technical requirements for each Data Link Application are related directly to the Operational Message Exchange Characteristics of the ATM Applications that they support. By literature analysis, the study team has applied appropriate technical requirements to each of the Operational Message Exchange Characteristics. This mapping is also shown in Table 1.

2.1.6 Table 2 records the Operational Message Exchange Characteristics appropriate to each ATM Application and also the Data Link Services appropriate to each ATM Application.

2.1.7 Data Link Services are provided by Data Link Applications. A single Data Link Application may provide several Data Link Services. For example, the CPDLC Data Link Application provides the ACL, ACM, COTRAC, DCL and DSC Data Link Services. Table 3 provides the mapping between Data Link Services and Data Link Applications.

2.1.8 Data Link Applications may support several ATM Applications, and hence may need to support several different levels of technical requirements. For example, the ADS Data Link Application has a range of possible technical requirements depending on the ATM Application supported. For example, the technical requirements for airborne separation are more exacting than for airborne spacing. Hence the study team has sub-divided each Data Link Application according to the technical requirements.

2.1.9 The next stage in the analysis relates the Data Link Applications to the ATM Application that they support and assigns timescales based on the timescales presented in the ATM Application roadmap. This results in a "Data Link Application Roadmap" which is presented in Tables 4 to 8 for each topology:

- Point-to-Point (Air-Ground)
- Point-to-Point (Air-Air)
- Air to Ground Broadcast
- Ground to Air Broadcast
- Air-Air Broadcast.

2.1.10 The decomposition of ATM Applications into Data Link Services, Data Link Applications and associated technical requirements was carried out using public documents which have gained widespread industry acceptance. Other public documents were used where appropriate to cross-check values. The primary references were as follows:

- [REF01] Enhanced TDMA for a VHF Data link System Matching the future European Air Traffic Management System requirements (E-TDMA), WP1, CEC DGXIII, 20/05/1998
- [REF03] Analyse Options For Initial A/G Data Networks, Phase 1, COM.ET2.ST15.1000 v.3.0, Eurocontrol, 07/1998
- [REF04] Analyse Options For Initial A/G Data Networks, Phase 3 Report Part 2, COM.ET2.ST15.3000-02, Eurocontrol, 07/1998
- [REF05] Operational Requirements For A/G Cooperative Air Traffic Services, AGC-ORD-01, ODIAC, Eurocontrol, 04/01
- [REF06] Future VHF Systems, Architecture Implementation Study, WP2220, Eurocontrol, 07/1999
- [REF07] ICAO Manual Of Air Traffic Services Data Link Applications , Doc. 9694-AN/955 First Edition, ICAO, 07/1999
- [REF08] Comprehensive ATN Manual (CAMAL), Part III, Applications Guidance Material, III4-248 to III4-252, Editor's Draft, 01/1999
- [REF09] ATN SARPs Sub-Volume II, "Air-Ground Applications", ICAO ATNP v.2.3, Editor's Draft, 1998

- [REF10] QoS Methodology Project, WP1 Interim Report, “An Assessment Methodology of Communication Infrastructure Operational Use through Quality of Service Tracing”, v.0A, 2001
- [REF11] Application Requirements for Data Communication Services, COM.ET2.ST11.1000 v.1.0, Eurocontrol, 1995
- [REF12] Technical Link Assessment Report, ADS-B Technical Link Assessment Team (TLAT), March 2001.

2.1.11 The study team believe that all of the source material used to derive the technical requirements provides a coherent validation of the technical requirements presented in this section. Specific information has been gathered as follows:

- The ODIAC [REF05] provides a basis for the description of all the D/L Services, the service transaction messages content and sequence, and other information such as periodicity and size when available. Distinction is made between D/L services-related information and D/L applications-related information.
- The ST15 Study [REF04] issued in 1998 tried to expose an implementation plan for D/L services and applications at the horizon 2000-2005. This reference has mainly been used to assess the hypothesis and the conclusions of the present document.
- The FVHF study [REF06] would also serve the same verification objective. A check has been performed systematically in order to remain coherent with the previous works.
- The ICAO D/L Application Manual [REF07] is a source for D/L application message formats.
- The CAMAL document [REF08] is a source for determination of message element size.
- The E-TDMA study [REF01] helps for the determination of the D/L services used in 2010, and particularly their periodicity on a typical flight, but only as a posteriori check.
- The TLAT report [REF12] provides range and message update requirements for broadcast ATM Applications[1].

2.2 Operational message exchange characteristics

2.2.1 In Table 1 the Operational Message Exchange Characteristics are mapped directly on to technical values for Quality of Service (QoS) parameters. The quantitative values delimiting the ranges are provided by cross-referencing the operational requirements with the technical requirements defined by ODIAC.

[1] Note that no requirements were obtained from this report for the range and acquisition times associated with broadcast applications in oceanic and remote regions. The study team has used engineering judgement for these based on twice the current separation standard for air-air (=120nm) and approximately three times the current separation standard for air-ground broadcast applications (= 200nm).

Characteristic	Operational Value	Technical Requirement
Time Criticality	Very High	1 to 3 sec 95% of the time: 5 sec 99.996% of the time
	High	5 sec 95% of the time: 15 sec 99.996% of the time
	Medium	10 sec 95% of the time: 20 sec 99.996% of the time
	Low	30 sec 95% of the time: 60 sec 99.996% of the time
Priority	Very High	Message in Emergency situations[1]
	High	Message in Tactical situations[2]
	Medium	Message in Strategic situations[3]
	Low	Message in Information situations[4]
Integrity	High	C, M, A, D: RER around 10^{-8}
	Medium	M, A, D: RER around 10^{-7}
	Low	M, A: RER around 10^{-6}
Availability	Very High	> 99.99%
	High	> 99.9%
	Medium	> 99.5%
	Low	< 99.5%
Exchanges Size	Very Short	Around 20 octets
	Short	Between 20 and 50 octets
	Medium	Between 50 and 250 octets
	Long	Over 250 octets
Message Frequency	Very High	Every second
	High	Every 2 - 15 seconds
	Medium	On event less than a minute
	Low	On event more than a minute
Throughput	Continuous/ Regular/ Sporadic/ Isolated	
Topology	Point-to-Point (Air/Ground)/ Point-to-Point (Air/Air)/ Air-Air Broadcast/ Air-Ground Broadcast/ Ground-Air Broadcast	
Range (for broadcast topologies only)	Very Long	> 150 nm
	Long	80 – 150 nm
	Medium	10 – 80 nm
	Short	< 10 nm
Acquisition time (for broadcast topologies only)	Long	>20s
	Medium	10 – 20s
	Short	< 10s

Table 1: QoS Levels

[1] Message in emergency situations: messages that refer to distress and emergency situations, as well as instruction to be executed immediately in order to preserve safety.

[2] Message in tactical situations: control messages requiring a change in current flight parameters in real time (within few seconds up to 15 seconds).

[3] Message in strategic situations: strategic control messages requiring a change in a flight parameters at a future point in time (within 20 seconds to 1 minute).

[4] Message in information situations: other messages not having any influence on flight parameters

2.2.2 Table 2 presents a summary of the Operational Message Exchange Characteristics and Data Link Services for each ATM Application (grouped by operational concept) along with the most appropriate Data Link Service. For each operational concept, the ATM Applications requiring the same Operational Message Exchange Characteristics and Data Link Services have been grouped together.

Operational Concept	**ATM Applications**	**Operational Message Exchange Characteristics**	**Data Link Service**
OC1: Provision of information from aircraft	APP1a: Enhanced Surveillance in terminal and en-route airspace, limited additional information being displayed to the controller APP1b: Enhanced Surveillance in terminal and en-route airspace providing wider range of downlink airborne parameters (DAP) APP1c: Enhanced surveillance accuracy for automation tools in terminal and en-route airspace	Time Criticality: High Priority: Strategic Integrity: Medium Availability: High Exchanges Size: Very Short Message Frequency: High Throughput: Continuous Topology: Point to Point (Air/Ground) or Air-Ground broadcast Range: Medium (terminal) or Long (en-route) Acquisition time: Medium (terminal) or Long (en-route)	CAP SAP
	APP1d: Fusion of current radar and ADS-B surveillance in terminal and en-route airspace	Time Criticality: Very High Priority: Tactical Integrity: Medium Availability: High Exchanges Size: Very Short Message Frequency: High Throughput: Continuous Topology: Air-Ground Broadcast Range: Medium (terminal) or Long (en-route) Acquisition time: Medium (terminal) or Long (en-route)	“ADS-B”

Operational Concept	ATM Applications	Operational Message Exchange Characteristics	Data Link Service
	APP1e: ATC surveillance using ADS-B in terminal and en-route airspace Note: As this application is sole means it has increased integrity and availability requirements	Time Criticality: Very High Priority: Tactical Integrity: High Availability: Very High Exchanges Size: Very Short Message Frequency: High Throughput: Continuous Topology: Air-Ground Broadcast Range: Medium (terminal) or Long (en-route) Acquisition time: Medium (terminal) or Long (en-route)	"ADS-B"
OC2: Enhanced communication efficiency	APP2a: Pilot preferences data link	Time Criticality: Medium Priority: Strategic Integrity: Medium Availability: Medium Exchanges Size: Short Message Frequency: Low Throughput: Sporadic Topology: Point to Point (Air/Ground) or Air-Ground broadcast Range: Medium (terminal) or Long (en-route) Acquisition time: Medium (terminal) or Long (en-route)	PPD
	APP2b: Strategic controller/pilot messages Note: The application is related to Controller/Pilot Strategic Clearance Exchanges	Time Criticality: Medium Priority: Strategic Integrity: Medium Availability: High Exchanges Size: Short Message Frequency: Medium Throughput: Regular Topology: Point-to-Point (Air/Ground)	DLIC ACL ACM DCL DSC
	APP2c: Support for increased automation Note: The application is related to Strategic ATM exchanges	Time Criticality: Low Priority: Strategic Integrity: Medium Availability: High Exchanges Size: Long Message Frequency: Low Throughput: Sporadic Topology: Point-to-Point (Air/Ground)	FLIPCY FLIPINT DYNAV

Operational Concept	ATM Applications	Operational Message Exchange Characteristics	Data Link Service
	APP2d: Trajectory negotiation Note: The application is related to Tactical ATM exchanges	Time Criticality: High Priority: Tactical Integrity: High Availability: Very High Exchanges Size: Long Message Frequency: Low Throughput: Sporadic Topology: Point-to-Point (Air/Ground)	COTRAC
OC3: ATSAW	APP3a: Enhanced visual acquisition (EVA) in remote and oceanic airspace	Time Criticality: High Priority: Tactical Integrity: Medium Availability: High Exchanges Size: Very Short Message Frequency: High Throughput: Continuous Topology: Air-Air Broadcast Range: Medium (terminal and en-route) or Long (oceanic) Acquisition time: Medium (terminal) or Long (en-route and oceanic)	"ADS-B"
	Note: ACL is included to support initiation of the application	Time Criticality: High Priority: Tactical Integrity: High Availability: High Exchanges Size: Medium Message Frequency: Low Throughput: Sporadic Topology: Point-to-Point (Air/Ground)	Voice (or ACL)

Operational Concept	ATM Applications	Operational Message Exchange Characteristics	Data Link Service
	APP3b: Enhanced visual acquisition (EVA) in terminal airspace APP3c: Enhanced visual approaches APP3d: Traffic situational awareness in core and transitional en-route airspace	Time Criticality: Very High Priority: Tactical Integrity: Medium Availability: High Exchanges Size: Very Short Message Frequency: High Throughput: Continuous Topology: Air-Air Broadcast Range: Medium (terminal and en-route) or Long (oceanic) Acquisition time: Medium (terminal) or Long (en-route and oceanic)	"ADS-B"
		Time Criticality: Very High Priority: Tactical Integrity: Medium Availability: High Exchanges Size: Very Short Message Frequency: High Throughput: Continuous Topology: Ground-Air Broadcast Range: Medium (terminal) or Long (en-route) Acquisition time: Medium (terminal) or Long (en-route)	"TIS-B"
	Note: ACL is included to support initiation of the application.	Time Criticality: High Priority: Tactical Integrity: High Availability: High Exchanges Size: Medium Message Frequency: Low Throughput: Sporadic Topology: Point-to-Point (Air/Ground)	Voice (or ACL)
OC4: Provision of information to aircraft	APP4a: Provision of D-OTIS (ATIS, METAR) and D-RVR APP4b: Provision of full range of uplink information services	Time Criticality: Medium Priority: Strategic Integrity: High Availability: High Exchanges Size: Long Message Frequency: Low Throughput: Sporadic Topology: Point-to-Point (Air/Ground) or Ground-Air Broadcast Range: Medium (terminal) or Long (en-route) Acquisition time: Medium (terminal) or Long (en-route)	D-ATIS METAR D-RVR NOTAM SNOW-TAM D-SIGMET

Operational Concept	ATM Applications	Operational Message Exchange Characteristics	Data Link Service
OC7: Dynamic route availability	APP7a: Provision of information on route availability	Time Criticality: Low Priority: Strategic Integrity: Medium Availability: High Exchanges Size: Long Message Frequency: Low Throughput: Isolated Topology: Point-to-Point (Air/Ground)	DYNAV
OC9: Airborne spacing	APP9a: Airborne spacing in en-route and terminal airspace APP9b: Crossing and passing in en-route airspace APP9c: Final approach spacing APP9d: Departure spacing	Time Criticality: Very High Priority: Tactical Integrity: High Availability: High Exchanges Size: Very Short Message Frequency: High Throughput: Continuous Topology: Air-Air Broadcast Range: Medium (terminal and en-route) or Long (oceanic) Acquisition time: Medium (terminal) or Long (en-route and oceanic)	“ADS-B”
		Time Criticality: Very High Priority: Tactical Integrity: High Availability: High Exchanges Size: Very Short Message Frequency: High Throughput: Continuous Topology: Ground-Air Broadcast Range: Medium (terminal) or Long (en-route) Acquisition time: Medium (terminal) or Long (en-route)	"TIS-B”
	Note: ACL is included to support initiation of the application	Time Criticality: High Priority: Tactical Integrity: High Availability: High Exchanges Size: Short Message Frequency: Low Throughput: Sporadic Topology: Point-to-Point (Air/Ground)	Voice (or ACL)

Operational Concept	ATM Applications	Operational Message Exchange Characteristics	Data Link Service
OC10: Airborne Separation	APP10a: Airborne separation in oceanic and remote airspace APP10b: Airborne separation in en-route and terminal airspace APP10c: Final approach separation Note: Separation requires increased availability over spacing (OC9)	Time Criticality: Very High Priority: Tactical Integrity: High Availability: Very High Exchanges Size: Very Short Message Frequency: High Throughput: Continuous Topology: Air-Air Broadcast Range: Medium (terminal and en-route) or Long (oceanic) Acquisition time: Medium (terminal) or Long (en-route and oceanic)	"ADS-B"
		Time Criticality: Very High Priority: Tactical Integrity: High Availability: Very High Exchanges Size: Very Short Message Frequency: High Throughput: Continuous Topology: Ground-Air Broadcast Range: Medium (terminal) or Long (en-route) Acquisition time: Medium (terminal) or Long (en-route)	"TIS-B"
	Note: ACL is included to support initiation of the application	Time Criticality: High Priority: Tactical Integrity: High Availability: High Exchanges Size: Short Message Frequency: Low Throughput: Sporadic Topology: Point-to-Point (Air/Ground)	Voice (or ACL)

Operational Concept	ATM Applications	Operational Message Exchange Characteristics	Data Link Service
OC11: Airborne Self-Separation	APP11a: Cluster control in ATC managed airspace APP11b: Autonomous operations in FFAS	Time Criticality: Very High Priority: Tactical Integrity: High Availability: Very High Exchanges Size: Very Short Message Frequency: High Throughput: Continuous Topology: Air-Air Broadcast Range: Medium (terminal and en-route) or Long (oceanic) Acquisition time: Medium (terminal) or Long (en-route and oceanic)	"ADS-B"
	Note: Aircraft-Aircraft Data Exchange is possibly included to support negotiation between aircraft	Time Criticality: Very High Priority: Tactical Integrity: High Availability: High Exchanges Size: Medium Message Frequency: Low Throughput: Sporadic Topology: Point-to-Point (Air/Air)	Air-Air Data Exchange ("PPDLC" Services Not defined by ODIAC)
	Note: ACL is included to support initiation of the application	Time Criticality: High Priority: Tactical Integrity: High Availability: High Exchanges Size: Short Message Frequency: Low Throughput: Sporadic Topology: Point-to-Point (Air/Ground)	Voice (or ACL)
OC12: ATSAW on ground	APP12a: Surface enhanced visual acquisition APP12b: Runway and final approach occupancy awareness	Time Criticality: Very High Priority: Tactical Integrity: High Availability: High Exchanges Size: Very Short Message Frequency: Very High Throughput: Continuous Topology: Air-Air Broadcast Range: Short Acquisition time: Short	"ADS-B"

Operational Concept	ATM Applications	Operational Message Exchange Characteristics	Data Link Service
	APP12c: Enhanced IMC airport surface operations	Time Criticality: Very High Priority: Tactical Integrity: High Availability: Very High Exchanges Size: Very Short Message Frequency: Very High Throughput: Continuous Topology: Air-Air Broadcast Range: Short Acquisition time: Short	"ADS-B"
OC13: ATC surveillance and A-SMGCS	APP13a: Fusion of current terminal and/or surface radar with ADS-B surveillance	Time Criticality: Very High Priority: Tactical Integrity: Medium Availability: High Exchanges Size: Very Low Message Frequency: Very High Throughput: Continuous Topology: Air-Ground Broadcast Range: Short Acquisition time: Short	"ADS-B"
	APP13b: ATC surveillance using ADS-B at airports. Note: As this application requires 'sole means' ADS-B it has increased integrity and availability requirements	Time Criticality: Very High Priority: Tactical Integrity: High Availability: Very High Exchanges Size: Very Low Message Frequency: Very High Throughput: Continuous Topology: Air-Ground Broadcast Range: Short Acquisition time: Short	"ADS-B"
	APP13c: Routing	Time Criticality: High Priority: Tactical Integrity: High Availability: High Exchanges Size: Short Message Frequency: Low Throughput: Sporadic Topology: Point-to-Point (Air/Ground)	Voice (or ACL)

Operational Concept	ATM Applications	Operational Message Exchange Characteristics	Data Link Service
OC14: ATS in oceanic/remote areas	APP14a: Basic surveillance infrastructure via ADS-B in remote regions	Time Criticality: Very High Priority: Tactical Integrity: High Availability: Very High Exchanges Size: Very Short Message Frequency: High Throughput: Continuous Topology: Air-Ground Broadcast Range: Very long Acquisition time: Long	ATSAW “ADS-B”
	APP14b: ATS in oceanic/remote areas	Time Criticality: Medium Priority: Strategic Integrity: High Availability: High Exchanges Size: Very Short Message Frequency: Medium Throughput: Continuous Topology: Point to Point (Air-Ground)	ADS-C

Table 2: Operational Message Exchange Characteristics and Data Link Services for each ATM Application

2.3 Categorisation of technical requirements

2.3.1 Table 3 provides the mapping between Data Link Services and Data Link Applications as defined by ODIAC and ICAO.

Data Link Application	Data Link Service
CPDLC	ACL
	ACM
	COTRAC
	DCL
	DSC
	DYNAV
ADS-B	"ADS-B"[1]
	CAP
	PPD
	SAP
TIS-B	"TIS-B"[2]
D-FIS	D-ATIS
	D-SIGMET
	METAR
	NOTAM
	D-RVR
CM	DLIC
ADS-C	CAP
	FLIPCY
	FLIPINT
	PPD
	SAP
"PPDLC"[3]	Aircraft-to-Aircraft Data Exchanges

Table 3: Mapping between Data Link Application and Data Link Service

2.4 Data Link Application Roadmap

2.4.1 This section presents the Data Link Application Roadmap, showing the timescale for introduction of each Data Link Application and indicating the supported ATM Applications. Each Data Link Application has been sub-divided according to the specific level of 'Quality of Service'.

[1] "ADS-B" means that there is no specific ADS-B Data Link Services specified. In the previous table 2, it means that ATM Applications directly rely on ADS-B at the Data Link Application level.

[2] "TIS-B" means that there is no specific TIS-B Data Link Services specified. . In the previous table 2, it means that ATM Applications directly rely on TIS-B at the Data Link Application level.

[3] Not defined at this time. Currently, supported by voice rather than by data link.

2.4.2 The timescales have been derived by cross-referencing against the timescales for ATM Applications. These timeframes will be reviewed during Phase 2 when technology feasibility issues are considered.

2.4.3 The tables in this section also present the Operational Message Exchange Characteristics for each Data Link Application Category. These can be directly related to technical requirements using Table 1. For broadcast applications, specific clarification of the technical requirements for message frequency, range and acquisition has been provided by including values taken from the TLAT report [REF12].

2.4.4 Table 4 presents the Data Link Application categories and associated ATM Applications requiring point-to-point (air-ground) communications.

Data Link Application Category	ADAP-0	ADAP-1	D-FIS-0	ADS-C-0	ADS-C-1	CPDLC-0	CPDLC-1	CPDLC-2	CPDLC-3
Description	Infrequent downlink of aircraft parameters	Frequent downlink of aircraft parameters	Uplink of Aeronautical Information	Strategic Flight Plan Collaborative Exchanges[1]	Strategic ADS Service	Strategic Data Link	Tactical Data Link	Strategic Flight Plan Collaborative Exchanges	Tactical Flight Plan Collaborative Exchanges[2]
ATM Applications	APP2a	APP1a, APP1b, APP1c	APP4a, APP4b	APP2c	APP14b	APP2b	None[3]	APP2c APP7a	APP2d
Time Criticality	Medium	High	Medium	Low	Medium	Medium	High	Low	High
Priority	Strategic	Tactical	Strategic	Strategic	Strategic	Strategic	Tactical	Strategic	Tactical
Integrity	Medium	Medium	High	Medium	High	Medium	High	Medium	High
Availability	Medium	High	High	High	High	High	High	High	Very high
Exchange Size	Short	Very Short	Long	Long	Very Short	Short	Short	Long	Long
Message Frequency	Low	High	Low	Low	Medium	Medium	Medium or low	Low	Low
Throughput	Sporadic	Continuous	Sporadic	Sporadic or Isolated	Contin-uous	Regular	Regular or sporadic	Sporadic or Isolated	Sporadic
Timescales									
Initial	2006	2004	2006	2002	2004	2002	>2015	2002	2009
Widespread	2007	2007	2010	2009	2004	2004	>2015	2009[4]	2012

Table 4: Requirements for Point-to-Point (Air-Ground)

[1] This category is shared by ADS-C-based services (e.g. FLIPCY) and CPDLC-based services (e.g. DYNAV).

[2] CPDLC-3 Supporting COTRAC will not be implemented before 2015.

[3] Eurocontrol's view (ODIAC), shared by the study team, is that in 2015, Tactical Controller-Pilot Dialog will be supplied by voice, as primary mean, in all zones (Surface, TMA, En-route). Tactical CPDLC –based on data link – should be used only as back-up to voice. In the data link roadmap we have considered the nominal mode, not the back-up. Hence Tactical CPDLC is placed here as a marker but will not be included in the roadmap until later than 2015.

[4] APP7a has a late implementation date in relation to technical requirements

2.4.5 Table 5 presents the Data Link Application categories and associated ATM Applications requiring point-to-point (air-air) communications.

Data Link Application Category	AADE-0
Description	Air-Air Data Exchange
ATM Applications	APP11a, APP11b
Time Criticality	Very High
Priority	Tactical
Integrity	High
Availability	High
Exchange Size	Medium
Message Frequency	Low
Throughput	Sporadic
Timescales	
Initial	2013
Widespread	2018

Table 5: Requirements for Point-to-Point (Air-Air)

2.4.6 Table 6 presents the Data Link Application categories and associated ATM Applications requiring air-ground broadcast.

Data Link Application Category	ADAP-0	ADAP-1	ADS-B-A0	ADS-B-A2	ADS-B-S0	ADS-B-S1
Description	Infrequent downlink of aircraft parameters	Frequent downlink of aircraft parameters	Supplementary Means Surveillance	Sole Means Surveillance	Supplementary Surface Surveillance	Sole Means Surface Surveillance
ATM Applications	APP2a	APP1a, APP1b, APP1c	APP1d	APP1e, APP14a	APP13a	APP13b
Time Criticality	Medium	High	Very High	Very High	Very High	Very High
Priority	Strategic	Tactical	Tactical	Tactical	Tactical	Tactical
Integrity	Medium	Medium	Medium	High	Medium	High
Availability	Medium	High	High	Very High	High	Very High
Exchange Size	Short	Very Short	Very Short	Very Short	Very Short	Very Short
Message Frequency (/min)						
Surface	not used	not used	not used	not used	Very high (60)	Very high (60)
Terminal area	High (12)	High (12)	High (12)	High (12)	not used	not used
En route & transition	High (5)	High (5)	High (5)	High (5)	not used	not used
Remote & oceanic	not used	not used	not used	High (5)	not used	not used
Throughput	Sporadic	Continuous	Continuous	Continuous	Continuous	Continuous
Range						
Surface	not used	not used	not used	not used	10 nm	10 nm
Terminal area	60 nm	60 nm	60 nm	60 nm	not used	not used
En route & transition	150 nm	150 nm	150 nm	150 nm	not used	not used
Remote & oceanic	not used	not used	not used	200 nm	not used	not used
Acquisition						
Surface	not used	not used	not used	not used	<10 s	<10 s
Terminal area	10 s	10 s	10 s	10 s	not used	not used
En route & transition	24 s	24 s	24 s	24 s	not used	not used
Remote & oceanic	not used	not used	not used	24 s	not used	not used
Timescales						
Initial	2006	2004	2008	2011	2007	2006
Widespread	2007	2007	2010	2015	2009	2013

Table 6: Requirements for Air Ground Broadcast

2.4.7 Table 7 presents the Data Link Application categories and associated ATM Applications requiring ground-air broadcast.

Data Link Application Category	TIS-B-0	TIS-B-1	TIS-B-2	D-FIS-0
Description	Support for EVA applications	Support for Spacing Applications	Support for Separation Applications	Uplink of Aeronautical Information
ATM Applications	APP3b, APP3c, APP3d	APP9a, APP9b, APP9c, APP9d	APP10a, APP10b, APP10c	APP4a, APP4b
Time Criticality	Very High	Very High	Very High	Medium
Priority	Tactical	Tactical	Tactical	Strategic
Integrity	Medium	High	High	High
Availability	High	High	Very High	High
Exchange Size	Very Short	Very Short	Very Short	Long
Message Frequency (/min)				
Surface	not used	not used	not used	not used
Terminal area	High (12)	High (12)	High (12)	High (12)
En route & transition	High (5)	High (5)	High (5)	High (5)
Remote & oceanic	not used	not used	High (5)	not used
Throughput	Continuous	Continuous	Continuous	Sporadic
Range				
Surface	not used	not used	not used	not used
Terminal area	60 nm	60 nm	60 nm	60 nm
En route & transition	150 nm	150 nm	150 nm	150 nm
Remote & oceanic	not used	not used	200 nm	not used
Acquisition				
Surface	not used	not used	not used	not used
Terminal area	10 s	10 s	10 s	10 s
En route & transition	24 s	24 s	24 s	24 s
Remote & oceanic	not used	not used	not used	not used
Timescales				
Initial	2005	2006	2008	2006
Widespread	2008	2009	2015	2010

Table 7: Requirements for Ground-Air Broadcast

2.4.8 Table 8 presents the Data Link Application categories and associated ATM Applications requiring air-air broadcast.

Data Link Application Category	ADS-B-A0	ADS-B-A1	ADS-B-A2	ADS-B-S0	ADS-B-S1
Description	EVA Applications	Spacing Applications	Separation Applications	Supplementary Surface Surveillance	Sole Means Surface Surveillance
ATM Applications	APP3a, APP3b, APP3c, APP3d	APP9a, APP9b, APP9c, APP9d	APP10a, APP10b, APP10c, APP11a, APP11b	APP12a, APP12b	APP12c
Time Criticality	Very High	Very High	Very High	Very High	Very High
Priority	Tactical	Tactical	Tactical	Tactical	Tactical
Integrity	Medium	High	High	High	High
Availability	High	High	Very High	High	Very High
Exchange Size	Very Short	Very Short	Very Short	Very Short	Very Short
Message Frequency (/min)					
Surface	not used	not used	not used	High (60)	High (60)
Terminal area	High (12)	High (12)	High (12)	High (12)	High (12)
En route & transition	High (5)	High (5)	High (5)	not used	not used
Remote & oceanic	High (5)	not used	High (5)	not used	not used
Throughput	Continuous	Continuous	Continuous	Continuous	Continuous
Range					
Surface	not used	not used	not used	5 nm	5 nm
Terminal area	40 nm	40 nm	40 nm	10 nm	10 nm
En route & transition	40 nm	40 nm	40 nm	not used	not used
Remote & oceanic	120 nm	not used	120 nm	not used	not used
Acquisition					
Surface	not used	not used	not used	<10 s	<10 s
Terminal area	10 s	10 s	10 s	10 s	10 s
En route & transition	24 s	24 s	24 s	not used	not used
Remote & oceanic	24 s	not used	24 s	not used	not used
Timescales					
Initial	2005	2006	2008	2006	2007
Widespread	2008	2009	2018	2007	2009

Table 8: Requirements for Air-Air Broadcast

3 Assessment Framework

3.1 Introduction

3.1.1 The remainder of this report describes the proposed method for technology assessment and selection. This section considers the overall methodology in two phases:

- Individual Assessment: Characterisation of the individual technologies.
- Overall Assessment: Comparison of potential 'groups' of technologies designed to support the full operational requirement.

3.1.2 The link between the individual and overall assessments is the definition of inter-network architectures which provide a theoretical framework for the comparison of technology groups.

3.1.3 Sections 4 through 6 provide further details of the component technical, cost and industrial assessments.

3.2 Individual assessment

3.2.1 The individual assessment is performed under WP2100. The main inputs are the Phase 1 outputs, and in particular the detailed technical requirements[1] contained in Section 2.

3.2.2 WP2100 includes the technical assessment of individual data link technologies which is described here and the preparation of the overall technical assessment framework which is described in Section 3.3 below.

3.2.3 The first intended output of WP2100 is a description of intrinsic operating characteristics in terms of services provided and associated level of performances, along with feasible time scales, costs and industrial impact for each proposed candidate data link technology.

3.2.4 The individual technology assessment aims at carrying out for each individual candidate data link technology, three parallel assessment tasks:

- Individual technical assessment of the technical characteristics, assessment of the maturity and operational readiness and strengths and weaknesses of the proposed technologies. Technical assessment is described in Section 4.
- Individual cost assessment which includes the identification of unit costs associated with the technology. Cost assessment is described in Section 5.
- Individual industrial assessment which analyses the impact on European industry of including/excluding the candidate technology from the roadmap. Industrial assessment is described in Section 6.

3.3 Inter-network architectures

3.3.1 The second intended output of WP2100 is the definition of "reference" end-to-end inter-network architectures that can integrate either point-to-point or

[1] Referred to in this document as 'Phase 1 technical requirements'

broadcast technologies. These end-to-end architectures provide an overall technical assessment framework to check, in WP2210, whether groups of data link technologies can meet operational constraints imposed by selected ATM Applications – the Phase 1 requirements.

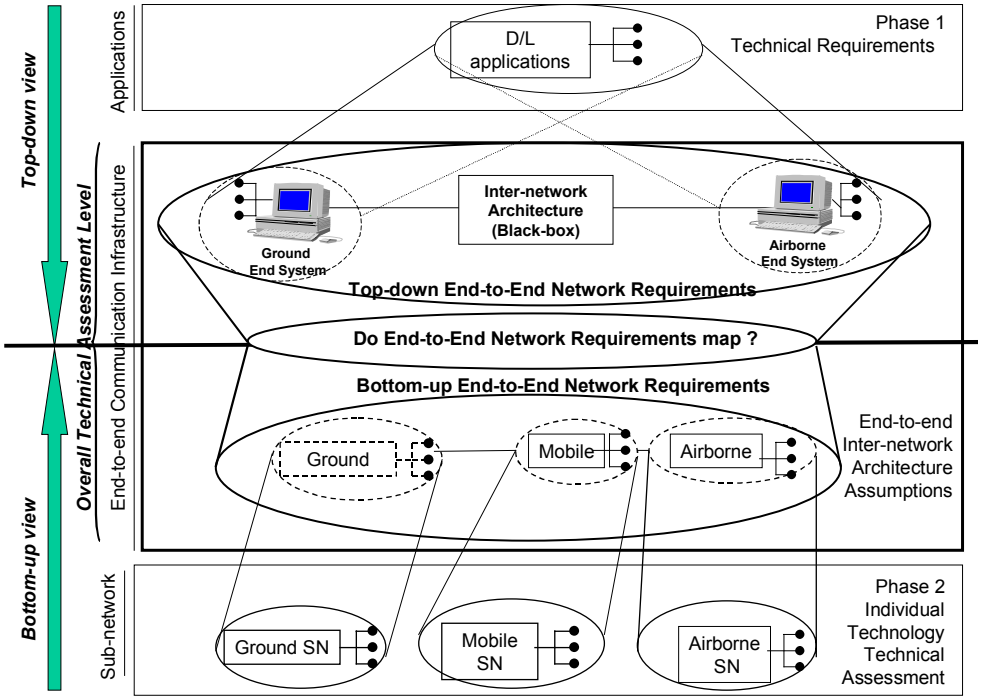


Figure 2: Overall Technical Assessment Framework

3.3.2 Figure 2 illustrates the end-to-end inter-network architecture as an "overall technical assessment level". Each End System is interfaced to the network through the inter-network architecture, which, as indicated by its name, interconnects several air-ground and ground networks. End System network requirements apply to the inter-network interface (See Figure 2).

3.3.3 The approach is to use a reference end-to-end inter-network architecture that provides a "constant" reference to analyse impact of different data link technologies at the end-to-end inter-network level.

3.3.4 Point-to-point data link technologies and broadcast data link technologies will be distinguished. Consequently, the following reference end-to-end inter-network architectures will be defined.

- For point-to-point assessment:
  - ATN-oriented end-to-end inter-network architecture;
  - FANS-1 oriented end-to-end inter-network architecture.
- For broadcast assessment:
  - Air/Ground and Air/Air inter-network architecture;
  - Ground/Air broadcast inter-network architecture.

3.3.5 The definition of topology scenarios will include the identification of potential comparison scenarios integrating stand-alone or mixed data link technologies,

and considering potential implementations to cover different Homogeneous Zones (for example ECAC Upper Airspace Core Area, major TMA).

3.4 Overall assessment

3.4.1 The overall assessment is a key driver of the technology selection performed in WP2210 and is central to the success of the project.

3.4.2 Using the technical comparison framework prepared in WP2100, it aims at determining which end-to-end communication architectures including one or several data link technologies, but also ground architecture and airborne components, can best meet technical requirements derived from operational needs. This allows a first technology selection from a pure technical point of view. Each retained technical option is then cost assessed so as to provide the overall cost. The impact on European Industry is also assessed for each retained technical option.

3.4.3 Main inputs to WP2210, are provided by Phase 1 and WP2100:

- Phase 1 technical requirements;
- Individual candidate technology characteristics (technical, cost, industrial impact);
- Reference end-to-end inter-network architectures for point-to-point and broadcast assessment;
- Potential comparison scenarios.

3.4.4 The method for WP2210 includes:

- Overall technical assessment: Assessment of the ability of candidate data link technologies or groups of technologies to meet operational constraints, including implementation time scales. The overall technical assessment method is to use reference end-to-end inter-network architectures, prepared in WP2100.
- Overall cost assessment: Assessment of the overall costs of the identified groups of technologies including costs of the associated ATM Applications.
- Overall Industrial Assessment: This assessment considers the impact on European industry of the proposed technical solutions and will consider the opportunities for European industry, their readiness for these opportunities and actions required to exploit them along with an assessment of likely impact on the European job market.

3.4.5 The intended output of WP2210 is the selection of data link technologies to be included in the roadmap and presentation of the preferred implementation scenario. WP2220, Roadmap Development, considers additional actions required to support the Data link Roadmap.

4 Technical Assessment Method

4.1 Introduction

4.1.1 The technical assessment considers the capability and maturity of the candidate technologies. As part of WP2100, an individual technical assessment is performed in which each technology is characterised. In WP2210, an overall technical assessment of potential 'sets' of data link technologies is performed using the inter-network architectures described in section 3.3.

4.2 Individual technical assessment

4.2.1 The method for individual technical assessment includes:

- Operating Characteristics: Consideration of the operating characteristics and services supported by the candidate data link technology.
- Maturity Assessment: Consideration of when the candidate data link technology could be deployed by analysis of standards, simulations and demonstrations. The objective is to assess the feasibility of Phase 1 timelines against maturity of candidate technologies.
- Strengths and Weaknesses: Consideration of salient intrinsic characteristics related both to technical and maturity aspects, not necessarily linked to an operational requirement.

4.2.2 The technical assessment is driven by the template provided in Annex A. This template will be completed for each candidate technology listed in Section 1.

4.2.3 The template includes consideration of:

- General description including service topology, frequency requirements and sub-system dependencies.
- Performance characteristics in terms of available Quality of Service.
- Maturity assessment in terms of spectrum availability, standards availability including certification and airworthiness requirements, level of support from stakeholders, and status of trials, demonstrations and operational deployment.
- Complexity assessment of the airborne and ground architectures including integration issues.
- A summary of the strengths and weaknesses of the proposed technologies.

4.3 Overall technical assessment

4.3.1 The overall technical assessment will consider the suitability of a number of proposed scenarios to meet the Phase 1 requirements. Each scenario will consist of a group of data link technologies including proposed implementation timeframes.

4.3.2 The inter-network architectures provide the technical framework for this comparison.

4.3.3 The mapping results - convergence or gap, including implementation time scales – will determine if:

- The technical option meets all operational needs
- The technical option meets the majority, but not all, of the operational needs
- The technical option does not meet the majority of the operational needs

4.3.4 This analysis will provide evidence that a proposed set of technologies are able, or are not able, to meet the Phase 1 requirements. This analysis will be augmented by the overall cost and industrial assessments in selecting the final technology set.

5 Cost Assessment Method

5.1 Introduction

5.1.1 The introduction of Data Link Services in European ATM will cause significant costs, which will be incurred by diverse stakeholders including:

- Aircraft Operators – including additional avionics, maintenance, crew training, and training of maintenance engineers, installation costs.
- ANSPs – including communications infrastructure, control centre upgrades including potential changes to Controller Work Position (CWP), Flight Data Processor (FDP) and Radar Data Processor (RDP), controller training, training of maintenance engineers, running costs, communications charges, land rental.

5.1.2 The purpose of the cost assessment is to enable:

- Cost comparisons between technical options;
- The overall cost of potential scenarios to be estimated relative to a reference scenario.

5.1.3 A technical option corresponds to all systems and activities that are required to implement and provide a certain set of ATM Applications over an Homogeneous Zone (HZ) with a certain combination of candidate technologies. It should be noted that one particular HZ may be covered by different technical options. In the same way, a technical option may be reduced to a single candidate technology.

5.1.4 The purpose of the cost assessment is to calculate the marginal costs of new developments relative to the current plans for ATM development in Europe. Hence, the costs of each individual candidate technology will be assessed against a reference scenario that assumes the baseline technologies which are currently in operation or which have been mandated and also the current investment plans for sustainment of current ground infrastructure.

5.1.5 The cost assessment will be performed at a high level to produce an 'order of magnitude' costs only. Costs have been classified as technology specific or general and as capital or annual:

- Technology specific costs are those which change with technology selection, for example the cost of a ground station or airborne radio.
- General costs are those which are common to all technologies or a significant sub-set of technologies. For example a Communications Management Unit is required to support point-to-point technologies but not broadcast technologies.
- Capital costs are one-off costs associated with the purchase of equipment.
- Annual costs are costs which are incurred in all subsequent years, for example equipment maintenance.

5.1.6 The cost assessment will refer to a fixed period, in order to consider the impact of recurrent costs in the comparison of the different options. In the "Guidelines for the economic appraisal of EATCHIP projects" (EUROCONTROL, v1.2, August 1996), it is indicated that a reasonable lifetime and analysis period for

economic appraisal of new operational ATC equipment is in the order of 10 years. In this case however, the period of 2003 to 2020 will be used to ensure that the overall cost of the proposed roadmap is calculated.

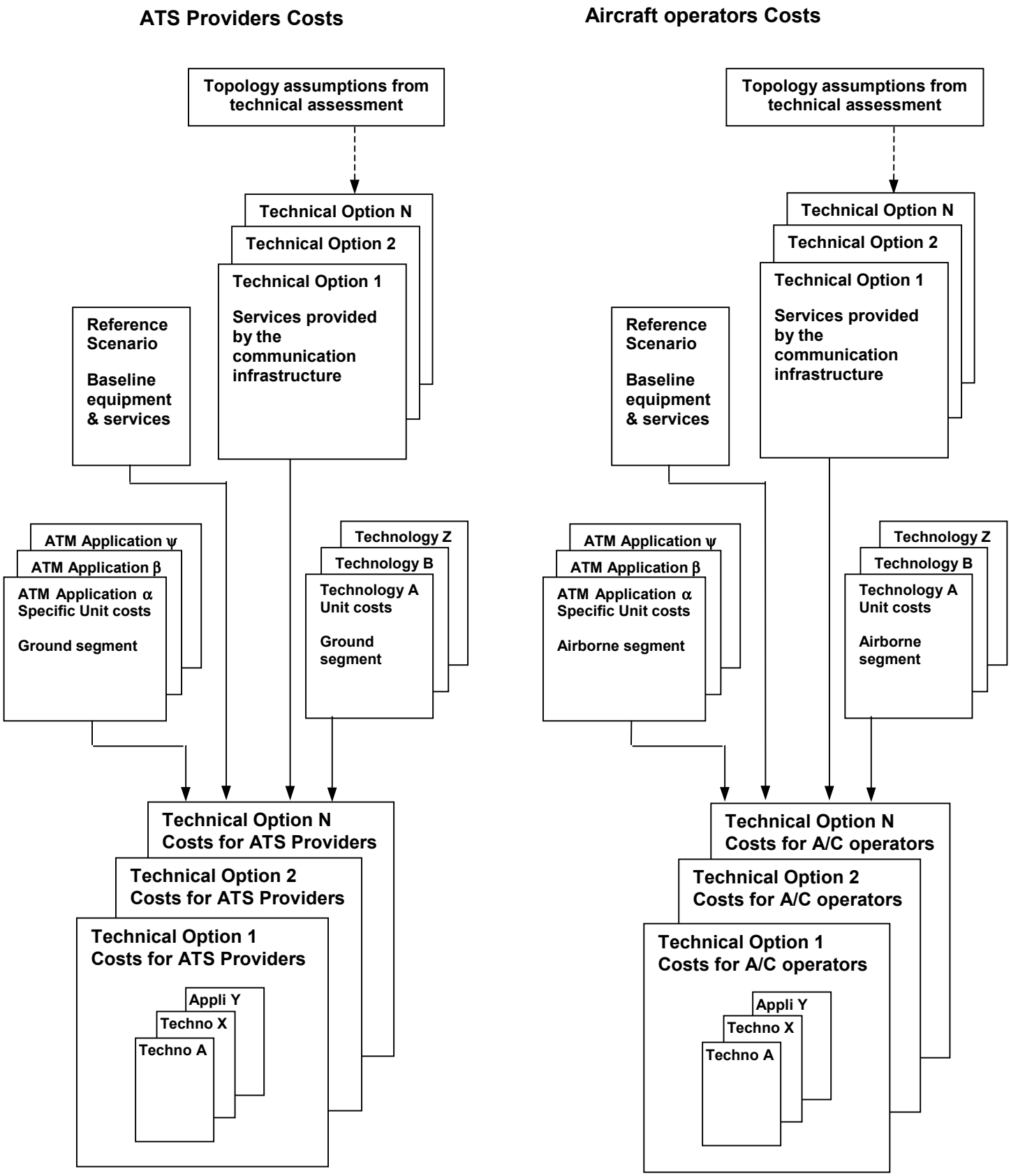
5.1.7 It should be noticed that most of the costs directly incurred by the ANS providers are paid indirectly by the aircraft operators through ATS charges. To be more precise, theoretically, additional ATS charges should be equal to the difference between the costs and the benefits generated by the studied option from the ATS provider's viewpoints. However, in the present case, as ATS providers costs are assessed on an airspace volume that does not correspond to the fleet sample which is the basis of the airborne cost assessment, it is not possible to easily transfer ATS costs to the aircraft operators. Nevertheless, when presenting the results from the aircraft operators viewpoint, it will be emphasised that the costs incurred by the ANS providers represent an important element in the position of the aircraft operator towards a new system/concept.

5.2 General approach

5.2.1 The general approach for the cost assessment for each stakeholder is presented in the diagram below.

5.2.2 The costs of each technical option are assessed relative to the reference scenario for:

- The unit costs specific to each technology,
- The unit costs specific to each ATM Application,
- The description of each technical option, notably in terms of technologies involved, and HZ considered (or applications considered),


ATS Providers Costs
Topology assumptions from technical assessment
Technical Option N
Technical Option 2
Technical Option 1
Services provided by the communication infrastructure
Reference Scenario
Baseline equipment & services
ATM Application ψ
ATM Application β
ATM Application α
Specific Unit costs
Ground segment
Technology Z
Technology B
Technology A
Unit costs
Ground segment
Technical Option N
Costs for ATS Providers
Technical Option 2
Costs for ATS Providers
Technical Option 1
Costs for ATS Providers
Appli Y
Techno X
Techno A
Aircraft operators Costs
Topology assumptions from technical assessment
Technical Option N
Technical Option 2
Technical Option 1
Services provided by the communication infrastructure
Reference Scenario
Baseline equipment & services
ATM Application ψ
ATM Application β
ATM Application α
Specific Unit costs
Airborne segment
Technology Z
Technology B
Technology A
Unit costs
Airborne segment
Technical Option N
Costs for A/C operators
Technical Option 2
Costs for A/C operators
Technical Option 1
Costs for A/C operators
Appli Y
Techno X
Techno A

5.3 Reference scenario

5.3.1 Before identifying the specific data link equipment required in each option, it is essential to clearly state the 'baseline' equipment that is assumed to be already on board and on the ground whatever the option.

5.3.2 The "Context Document" (D1020), identifies the baseline as:

- ACARS supported by AVPAC, HFDL and AMSS
- Voice supported by 25kHz and 8.33 kHz
- Mandated Mode S equipment

5.3.3 The period of analysis will start in 2003; regarding data link capability of the fleet, it is assumed that at this time, the FANS 1/A communication environment will be widely available on production aircraft (for Airbus, that means 1 ATSU, 2 DCDU, 2 attention getters). This does not mean however that all aircraft will be FANS 1/A equipped from this period, as the FANS 1/A equipment rate will strongly depends on the airlines policy, notably for AOC. Thus, up to 2015, there will be several coexisting types of onboard architecture for which new data link technologies (and service equipment) will be implemented. The picture of the baseline data link capabilities of the aircraft fleet flying over Europe will then have to be identified; the corresponding data will be gathered in the ***"reference scenario data" spreadsheet*** of the costs assessment file.

5.3.4 Similarly, on the ground side, it is likely that some data link capabilities or compatible equipment will be already deployed for other purposes than the Data Link Services considered in the present study. For instance, Mode S stations are supposed to be deployed in the short term for surveillance purposes, so that only a few elements would be necessary to complete this sub-network. All data and assumptions related to this reference scenario will have to be stated, and the associated figures entered in the ***"reference scenario data" spreadsheet*** of the costs assessment file.

5.4 Clarifying technical options

5.4.1 A preliminary task of the cost assessment will consist of clarifying the technical options to be evaluated.

5.4.2 These options should be derived from the technical assessment results: the technical assessment task should identify the relevant combinations of technical infrastructures that provide the technical requirements derived from operational needs of ATM Applications.

5.4.3 Each technical option will be described in terms of:

- Concerned homogeneous zone i.e. to which the technical option is applicable,
- ATM Applications to be provided,
- Type of air traffic (long-haul, medium-haul, short-haul, etc.),
- Technologies involved: for each candidate technology the required airborne and ground architecture (in addition to, or replacement of, what is already included in the reference scenario).

5.5 Costs quantification from ATS providers viewpoint

5.5.1 The following table identifies the individual cost elements considered for ANSPs. Costs are expressed per airport and per area control centre. A range of costs will be considered, but an average cost will be used for comparative purposes.

	Capital Costs	**Annual Costs**
Technology Specific	Communications Infrastructure including: • equipment costs • installation and certification • maintenance engineer training	Communications Charges Running costs including: • maintenance • routine calibration • land rent • electricity etc
General	System Upgrades including • FDP • RDP • CWP Controller Training	It will be assumed that system upgrades do not incur additional running costs or require training for maintenance engineers (ie it is assumed that such costs are included within running costs for the baseline scenario).

Table 9: ANSP Cost Categories

5.5.2 The costs of each option, for each year of the analysis period, will be presented in a spreadsheet dedicated to the option considered (cf. ***"TOy" spreadsheets*** in the costs assessment Excel file).

5.5.3 In order to be able to compare the different technical options, the costs will be calculated **for a certain airspace volume** (or a certain surface unit) that will be fixed prior to any quantification. Thus, if for instance the coverage of a technology A ground station is wider than that of a ground station using a competitive technology (say B), the results will take into account that technology A requires less stations than technology B.

5.5.4 The main inputs for the quantification are:

- Ground communication architecture over the concerned area, or over homogeneous zones, given in the detailed description of each technical option,
- Unit costs: unit price of each equipment/device (or independent element), certification and installation unit costs; associated training cost per controller, and per maintenance personnel; unit cost for the yearly maintenance of the equipment; unit costs will be gathered and classified according to either the technology or the ATM Application they are specific to (cf ***"ground segment unit costs" spreadsheet*** of the costs assessment file).

5.6 Cost quantification from the aircraft operators viewpoint

5.6.1 The following table identifies the individual cost elements considered for aircraft operators. Costs will be expressed per aircraft for Air Transport and General Aviation.

	Capital Costs	Annual Costs
Technology Specific	Avionics including ▪ Radio/transponder ▪ Antenna Installation Costs (specific to radio and antenna) Training maintenance engineers Training Flight Crew	Equipment maintenance Communication costs
General	Avionics ▪ CMU (point-point only) ▪ CDTI (broadcast only) Installation Cost (to include upgrades to other avionics required for integration) Training maintenance engineers Training Flight Crew	Equipment maintenance

Table 10: Aircraft Operator Cost Categories

5.6.2 The annual costs of each option, for each year of the analysis period, will be presented in a spreadsheet dedicated to the option considered (cf. ***"TOy" spreadsheets*** in the costs assessment Excel file).

5.6.3 In order to take into account the different coexisting airborne architectures, the costs will be calculated for a **representative sample of aircraft** that will be defined prior to any quantification.

5.6.4 The main inputs for the quantification are:

- Airborne communication architecture depending on aircraft types, given in the detailed description of each technical option,
- Aircraft fleet data by region and by types of aircraft,
- Part of the fleet to be equipped: international, regional, or those registered in Europe[1].
- The rate of equipage required to maximise benefits.
- Unit costs: unit price of each equipment (or independent element), certification and installation unit costs; associated training cost per pilot, and per maintenance personnel; unit cost for the yearly maintenance of the equipment; unit costs will be gathered and classified according to either the technology or the ATM Application they are specific to (cf ***"airborne segment unit costs" spreadsheet*** of the Costs assessment Excel file).

5.6.5 In the case some data link communications go through a network operated by a communications service provider, the ANS providers will have to pay

[1] It is normal to consider the European registered fleet and hence exclude, for example, US registered aircraft. Where Europe and US follow different technology options this practise may not be optimum.

transmission charges: these kind of charges are usually invoiced by applying a unit price per transmitted kilobit to the total volume of the communications.

5.6.6 The yearly mobile data link communication volumes will be estimated from:

- the average communication volume going through the service providers network, per time unit and per data link equipped aircraft: inputs for this would be the message sizes of services considered, the D/L services deployment schedule, etc.
- the number of D/L equipped aircraft, for each year of the analysis period.

5.7 Presentation of the results

5.7.1 Each option has its own distribution of costs over time: to capture this time effect, an almost universal method consists in calculating the present value (or sometimes the value in the reference year) of each cost. The present value is defined as follows: "If a project offers a dollar benefit N years in the future, the Present Value of that future benefit is an amount such as the project investor would be completely indifferent between receiving the Present Value now and the Future Value after N years."

5.7.2 In practise, the Present Value is obtained by applying a Time Discounting Factor (TDF) to the future value. This factor depends on the year of the future value and on the Time Discounting Rate (TDR) which is a compromise between the minimum profitability envisioned by the company and the capital costs (dividends and market loan rate). In the CBA of ATM project, a Time Discounting Rate of 10% is currently used.

5.7.3 The sum of all the Present Values gives the Net Present Value (NPV) of the project. This computation should be performed for each stakeholder and for each technical option.

5.7.4 When the NPVs are determined, it is interesting to assess the impact of small variations of key parameters on the final results: this is the objective of the sensitivity analysis, which will be performed for the main parameters (e.g. communication unit cost) and in particular for those in which there is no strong confidence.

5.7.5 Then, in the very last phase of this WP, results will be analysed in the light of the sensitivity analysis and remembering the main assumptions in the calculations.

6 Industrial Assessment Method

6.1 Introduction

6.1.1 The purpose of the industrial assessment is to consider the impact on European industry of the proposed technical solutions. The assessment will be conducted in two phases:

- Individual assessment: Consideration of the readiness of manufacturing industry to exploit a particular technology.
- Overall assessment: Consideration of the impact of a selected group of technologies on manufacturing industry, airspace users and ANS providers including job creation.

6.2 Individual industrial assessment

6.2.1 The individual industrial assessment will consider, for a particular technology:

- Which companies are actively developing the technology,
- The status of that development,
- The anticipated time to market,
- The risks associated with the development,
- If patent or licensing restrictions exist,
- The level of industrial support,
- View of the maturity of the technology,
- Maturity of the process required to integrate the technology within the airframe,
- The extent to which the technology represents an opportunity for European industry.

6.2.2 The views of equipment/technology vendors and the views of aircraft manufacturers/system integrators will be sought separately.

6.2.3 Where the technology is not exclusively used for Air Traffic Management (for example the proposed 3G/UMTS), the following questions will also be considered:

- Are there business drivers in other sectors likely to promote development of technology?
- What fraction of the total market will ATM Applications represent?
- What is the status of the development of the technology in other sectors?

6.2.4 A number of relevant manufacturing companies will be interviewed in order to determine the required information.

6.3 Overall industrial assessment

6.3.1 During the overall industrial assessment, the following additional factors will be considered:

- Impact of aircraft operators/airspace users. Do the selected technologies cause particular issues for aircraft operators, for example proliferation of avionics and availability of avionics for all market sectors including general aviation)? What additional actions are required to support airspace users in deploying the technologies/applications?
- Impact on ANSPs. Do the selected technologies (and in particular the selected applications) cause particular issues with ANSPs? Are the ANSPs ready to implement the applications? What additional actions are required to support the ANSPs in deploying the technologies/applications?
- Likely impact on European job market.

A Assessment Template for Technical Assessment

A.1.1 The template enables all the required characteristics, for both point-to-point and broadcast technologies, to be documented.

A.1.2 All Characteristics listed below are considered from the standpoint of a link layer service user.

Level	Parameter	Value	Notes[1]	Rationale[2]/Comment
Service General Description				
Upper Link Layer Service Interface	Service Topology	Point-to-point, air-air broadcast, uplink broadcast, downlink broadcast		High level Identification so as to map on requirements following the topology/directionality axis
Upper Link Layer Service interface	ATN compliance	Y/N		Only for point-to-point; useful at a later stage for overall technical assessment taking into account infrastructure topology scenarios
Upper Link Layer Service interface	Ability to support multiple user profiles through QoS management mechanisms (provided by lower layers, visible at the LL service interface) + impacted performance characteristics			*If applicable, should result in more than one value for the impacted performance characteristics below*
Physical	Frequency Band			Identification of potential interference with other media at the overall assessment stage RF Channels: Nr of channels, channel width, frequency
Physical	RF Channels			
Physical	Modulation scheme			Assessment of actual risk for interference with other media using close RF channels

[1] Including References for values when applicable

[2] That is to say: Rationale for description of this parameter in the framework; this column is to be discarded when actually using the template.

Level	Parameter	Value	Notes[1]	Rationale[2]/Comment
Sub-system	Dependencies			Assessment of technical risk, and/or limiting factors in the deployment and use. - Dependence upon deployment of other systems/technologies - Or potential shared use by other systems
Performance characteristics				
Upper Link Layer Service Interface	Transmission Delay			Mean Value 95% value Mapping of the QoS characteristic across the model Corresponds to Latency for broadcast; transfer delay for point to point
Sub-system	Availability			Mapping of the QoS characteristic across the model; considering air and ground infrastructures
Upper Link Layer Service Interface	Integrity			Mapping of the QoS characteristic across the model
Upper Link Layer Service Interface	Continuity of function			Probability of Failure, Alert delay
Upper Link Layer Service Interface	Capacity			Point to point: throughput per aircraft Broadcast: Update period, max. nr of aircraft
Upper Link Layer Service Interface	Coverage (airspace category) & Range			Mapping of the spatial coherence characteristic across the model; also useful for overall technical assessment taking into account infrastructure topology scenarios G/A Broadcast: relationship with service volume

Level	Parameter	Value	Notes[1]	Rationale[2]/Comment
Upper Link Layer Service Interface	Priority Management			Ability to manage different levels of priority; number of priority levels Mapping of ATN Priority parameter (Network level)
Maturity Assessment				
Physical	Frequency availability (allocation status)			Global allocation required ? Global allocation status Regional allocation required ? Regional allocation status Local allocation required ? local allocation status
Standards	Available Standards Missing Standards Expected Completion Date			
Level of Support	Various Stakeholders Commitments status : - Associated R&D & Simulations programmes status - CBA Availability - Level of support by ANSPs - Mandatory Carriage Status – Industry: Air and ground systems development programme status Ground Deployment plans status - Aircraft fleet equipment plans status			
Industry/Airworthiness/Certification	Certification Issues/ Status / timeline			
	Prototyping status			Pre-series prototype equipment availability / timeline?
	Operational status			Certifiable/certified equipment availability / Location of deployed regions / timeline

Level	Parameter	Value	Notes[1]	Rationale[2]/Comment
	Conclusion: Feasibility Time Scale			Using above information
Complexity Assessment:				
	Airborne architecture constraints			
	Ground architecture constraints			
Strengths and weaknesses				
	Summary of Strong Characteristics			Useful for overall assessment, intrinsic characteristics (not necessarily linked to an operational requirement) Covering all above aspects
	Summary of Weak Characteristics			Useful for overall assessment, intrinsic characteristics (not necessarily linked to an operational requirement) Covering all above aspects

B Assessment Template for Cost Assessment Model

B.1 Reference Scenario Data

AIRBORNE SEGMENT	**Year 0**			
Fleet flying over Europe :				
Fleet registered in Europe				
Long-haul				
Medium-haul				
Short-haul				
Aircraft from other regions :				
Aircraft D/L capability				
None				
ACARS MU				
FANS 1/A (ATSU/CMU + DCDU + AG)				
FANS XX or next generation				
Baseline equipment on board				
VDR Mode 2				
AMSS AES				
HFDL equipment				
Mode S level 2 transponders				
Mode S level 4 transponders (ES)				
GROUND SEGMENT				
Number of Mode S stations (to upgrade with GDLP)				
VDL 2 ground stations				
VDL 4 ground stations				

B.2 Ground Segment Unit Costs

	Unit Cost	Comments
UAT specific equipment and operations		
Ground station (market price)		
Ground station installation and certification		
Ground station maintenance training		
Ground station maintenance costs per year		
…..		
VDL3 specific equipment and operations		
Ground station (market price)		
Ground station installation and certification		
Ground station maintenance training		
Ground station maintenance costs per year		
…..		
VDL4 specific equipment and operations		
Ground station (market price)		
Ground station installation and certification		
Ground station maintenance training		
Ground station maintenance costs per year		
…..		
1090 ES specific equipment and operations		
Upgrade of current Mode S station (equip + installation)		
Additional maintenance training		
…..		
Mode S data link specific equipment and operations		
Upgrade of current Mode S station (equip + installation)		
Additional maintenance training		
…..		
Gatelink specific equipment and operations		
….		
APPLICATION A specific equipment and operations		
….		
APPLICATION B specific equipment and operations		
….		

B.3 Airborne Segment Unit Costs

	Unit Cost	Comments
UAT specific equipment and operations		
Airborne equipment (market price)		
Airborne equipment installation and certification		
Airborne equipment maintenance training		
Airborne equipment maintenance costs per year		
…..		
VDL3 specific equipment and operations		
Airborne equipment (market price)		
Airborne equipment installation and certification		
Airborne equipment maintenance training		
Airborne equipment maintenance costs per year		
…..		
VDL4 specific equipment and operations		
Airborne equipment (market price)		
Airborne equipment installation and certification		
Airborne equipment maintenance training		
Airborne equipment maintenance costs per year		
…..		
1090 ES specific equipment and operations		
Upgrade of current Mode S transponder		
Additional maintenance training		
…..		
Mode S data link specific equipment and operations		
Upgrade of current Mode S transponder		
Additional maintenance training		
…..		
NGSS specific equipment and operations		
….		
Gatelink specific equipment and operations		
….		
APPLICATION A specific equipment and operations		
….		
APPLICATION B specific equipment and operations		
….		

B.4 Technical Option # (TO#)

	Year 1	Year 2	Year 3	Year 4
COSTS for ATS PROVIDERS				
Technology X specific costs				
Technology Y specific costs				
…				
Application A specific costs				
Application B specific costs				
…				
Total costs				
Present values				
Net Present Value				
COSTS for AIRCRAFT OPERATORS				
Technology X specific costs				
Technology Y specific costs				
…				
Application A specific costs				
Application B specific costs				
…				
Total costs				
Present values				
Net Present Value				