CONTRACT N° : G4RD-2000-00228

PROJECT N° : GRD1-1999-10516

ACRONYM : MA-AFAS

TITLE : THE MORE AUTONOMOUS - AIRCRAFT IN THE FUTURE AIR TRAFFIC MANAGEMENT SYSTEM

D14 – Operational Services and Environment Definition

AUTHOR: EUROCONTROL

PROJECT CO-ORDINATOR : BAE SYSTEMS

PRINCIPAL CONTRACTORS :

Airtel ATN Ltd (Ireland)	DERA (UK)
ETG (Germany)	EUROCONTROL (France)
NLR (Netherlands)	

ASSISTANT CONTRACTORS:

Airsys ATM (France)	Alenia Difesa (Italy)
AMS (Italy)	DLR (Germany)
FRQ (Austria)	Indra Sistemas (Spain)
NATS (UK)	SCAA (Sweden)
SC-TT (Sweden)	Skysoft (Portugal)
SOFREAVIA (France)	Stasys Limited (UK)

Report Number :	**560/79672**
Project Reference number :	**MA-AFAS – WP1.4-EUROCONTROL**
Date of issue of this report :	**July-2003**
Issue No:	**3.0**
PROJECT START DATE :	**1/3/2000 DURATION : 36 months**

Project funded by the European Community under the 'Competitive and Sustainable Growth' Programme (1998-2002)

All enquiries related to this publication should be referred to:
EUROCONTROL

BP15 – 91222 Brétigny sur Orge
France
Tel. 33 1 69887500 Fax. 33 1 60851504

Operational Services and Environment Definition

for

More Autonomous – Aircraft in the Future

Air Traffic Management System

Deliverable D14

Document No. 560/79672
Issue 3.0

Contains 230 pages total
Comprising:
1 pages front matter
229 pages text and figures

Compiled by:	COFRAMI (Danièle Cloarec)	Title:	Systems Engineer
		Date:	15/07/2003
Approved by:	Eric Hoffman	Title:	Project Manager
		Date:	15/07/2003
Authorised by:	Alfie Hanna	Title:	MA-AFAS Project Manager
		Date:	

RECORD OF CHANGES

Issue	Date	Detail of changes
Draft 1.0	19-09-2000	Initial version
Draft 2.0	10-10-2000	
Draft 4.0	27/10/00	
Draft 5.0	15/01/01	
Draft 6.0	16/03/01	
Draft 7.0	10/04/01	
Issue 1.0	05/2001	Issue 1.0 (delivered to EC)
Issue 2.0	12/2001	Issue 2.0 (to be delivered to EC)
Issue 3.0	15/07/2003	Issue 3.0 (to be delivered to EC)

IMPORTANT NOTE: **ANY NEW VERSION SUPERSEDES THE PRECEDING VERSION, WHICH MUST BE DESTROYED OR CLEARLY MARKED ON THE FRONT PAGE WITH THE MENTION** ***OBSOLETE VERSION***

TABLE OF CONTENTS

Abbreviations

2D	2 Dimensions (ie Longitude and Latitude)
3D	3 Dimensions (ie Longitude, Latitude and Altitude)
4D	4 Dimensions (ie Longitude, Latitude, Altitude and Time)
A/C	Aircraft
ACARS	Aircraft Communications Addressing and Reporting System
ACC	Area Control Centre
ACL	ATC Clearance and information
ACM	ATC Communication Management
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance-Broadcast
AEEC	Airlines Electronic Engineering Committee
AFCS	Automatic Flight Control System (ie autopilot and autothrottle)
AFTN	Aeronautical Fixed Telecommunications Network
A/G	Air-Ground
AIP	Aeronautic Information Publication
AMHS	ATS Message Handling System
ANP	Actual/Achieved Navigation Performance
AoA	ACARS over AVLC
AOC	Airline Operations Centre
APP	Approach control
ARINC	Aeronautical Radio, Inc.
ASAS	Airborne Separation Assurance System
ASE	Application Service Element
ASTERIX	All-purpose STructured EUROCONTROL Radar Information Exchange
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
ATS	Air Traffic Services
ATSP	Air Traffic Service Provider
ATSU	Air Traffic Service Unit
A/V	Aircraft/Vehicle
AVLC	Aviation VHF Link Control
BIS	Boundary Intermediate System
B-RNAV	Basic Area Navigation
CAA	Civil Aviation Authority
CAS	Calibrated Air Speed
C-ATSU	Controlling ATSU
CD&R	Conflict Detection and Resolution
CDTI	Cockpit Display of Traffic Information
CIDIN	Common ICAO Data Interchange Network
CNS	Communication, Navigation, Surveillance
COM	Communications
COTRAC	Common Trajectory Coordination Service
CPDLC	Controller Pilot Data Link Communication
CSMA	Carrier Sense Media Access
CTOT	Calculated Take-Off Time
CWP	Controller Working Position
D8PSK	Differential 8-Phase Shift Keying
DAP	Downlink of Aircraft Parameters

D-ATSU	Downstream Air Traffic Service Unit
DCL	Departure Clearance
DFS	Deutsche Flugsicherung GmbH
DGNSS	Differential Global Navigation Satellite Service
DGPS	Differential Global Positioning System
DHP	Direct Host Protocol
DLIC	Data Link Initiation Capability (DLL service)
DLL	Data Link Logon
DME	Distance Measuring Equipment
DOP	Daily Operational Plan
DSB	Double-Side Band
DSC	Downstream Clearance
DSP	Data link Signal Processor
EOBT	Estimated Off Block Time
EGNOS	European Geostationary Navigation Overlay Service
ES	End System (ATN)
ETA	Estimated Time of Arrival
EUROCAE	European Organisation for Civil Aviation Equipment
FAF	Final Approach Fixes
FAS	Final Approach Segment
FAT	Final Approach Track
FCS	Flight Control System
FDPS	Flight Data Processing System
FFAS	Free Flight Airspace
FIR	Flight Information Region
FIS	Flight Information Service
FLIPCY	Flight Plan Consistency
FMP	Flight Manager Position
FMS	Flight Management System
FOM	Figure Of Merit
FSK	Frequency Shift Keying
G/G	Ground- ground
GACS	Generic ATN Communications Service
GBAS	Ground-Based Augmentation System
GES	Ground Earth Station
GNI	Ground Network Interface
GNLU	GNSS Navigation and Landing Unit
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
GRAS	Ground-based Regional Augmentation System
H24	24 Hour
HF	High Frequency
HIRO	High Intensity RWY Operation
HMI	Human Machine Interface
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organisation
ICC	Inter-Centre Communications
IDS	In Descent Spacing
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
ISO	International Standards Organisation
kB/s	Kilo Bits/seconde
LAAS	Local Area Augmentation System

LAN	Local Area Network
LFS	Level Flight Spacing
LNAV	Lateral Navigation
MAS	Managed Airspace
MA-AFAS	More Autonomous Aircraft in the Future ATM System
MCDU	Multipurpose Control and Display Unit
MHS	Message Handling Service
MLS	Microwave Landing System
MMR	Multi Mode Receiver
MSL	Mean Sea Level
MSSR	Monopulse Secondary Surveillance Radar
NAV	Navigation
NDB	Non-Directional Beacon
NEAN	North-European ADS-B Network
NPA	Non-Precision Approach
NUC	Navigation Uncertainty Category (Position UC and Velocity UC)
NUP	NEAN Update Program
OC	Operational Concept
OCM	Oceanic Clearance Message
OLDI	On-Line Data Interchange
OSED	Operational Services and Environment Definition
PA	Precision Approach
P-RNAV	Precision Area Navigation
PSR	Primary Surveillance Radar
PoA	Plain Old ACARS
PTT	Push To Talk
PVT	Position Velocity Time
QFE	Air-pressure at ground level
RA	Resolution Advisory
RADNET	RADar data exchange NETwork
RGS	Remote Ground Station
RIU	Radio Interface Unit
RNAV	Area Navigation
RNP1	Required Navigation Performance 1
ROT	RWY Occupancy Times
RSP	Required Surveillance Performance
R/T	Radiotelephony
RTA	Required Time of Arrival
RVSM	Reduced Vertical Separation Minima
SARPS	Standards And Recommended Practices
SATCOM	Satellite Communications
SBAS	Satellite Based Augmentation System
SIGMET	Significant Meteorological Data
SLC	Synchronous Link Control
SLOT	CTOT minus 5 plus 10 minutes
SMGCS	Surface Movement and Guidance Control System
SP	Service Provider (data link)
SQ	Squelch (break)
SSR	Secondary Surveillance Radar
STAR	Standard Arrival Route
STCA	Short Term Conflict Alert
STDMA	Self-organizing TDMA
SUA	Special Use Airspace
SUR	Surveillance

TACAN	Tactical Air Navigation
TCAS	Traffic alert and Collision Avoidance System
TCP	Trajectory Change Point
TCP/IP	Transmission Control Protocol/Internet Protocol
TIS-B	Traffic Information Service - Broadcast
TMA	Terminal Manoeuvre Area
TOD	Top Of Descent
TWR	Tower
TRACON	Terminal Radar Approach CONtrol
UMAS	Unmanaged Airspace
UTC	Co-ordinated Universal Time
VCS	Voice Communications System
VDB	VHF Data Broadcast
VDL2	VDL Mode 2
VDL3	VDL Mode 3
VDL4	VDL Mode 4
VFR	Visual Flight Rules
VNAV	Vertical Navigation
VOR	Very High Frequency Omni-directional Radio Range (Navaid)
VORTAC	VHF Omni-Range Tactical Air Navigation
WAN	Wide-Area Network
WGS84	World Geodetic System 84

1 Introduction

This document provides an Operational Services and Environment Definition (OSED), based on EUROCAE WG53 guidance, which should help to capture the operational environment characteristics of MA-AFAS applications, and in particular to define the characteristics of the simulations and flight experiments to be conducted by the MA-AFAS project in the 2002 timeframe

The OSED is used as the basis for assessing and establishing operational, safety, performance, and interoperability requirements for the related CNS/ATM system. The OSED identifies the air traffic services supported by MA-AFAS communications, navigation, and surveillance – as well as air traffic management – capabilities, and their intended operational environments and includes the operational performance expectations, functions and selected technologies of the related CNS/ATM system.

Airspace planners and airspace users are the primary users of the template to capture characteristics of the operational environment needed by system qualifiers to assess the safety, interoperability, and performance aspects of air traffic services supported within MA-AFAS scope.

The operational environment and resulting required assessment of a given air space includes a mix of aircraft with different system characteristics, including functional and performance, a variety of air traffic services, and modification of any other elements of the operational environment.

1.1 Operational scenario applied to MA-AFAS concept:

From the MA-AFAS concept defined in D9, it is the objective of this document to define operational scenario for the evaluation of the selected MA-AFAS applications (D13) on the ATM management. MA-AFAS scope is first to develop new airborne capabilities using the existing ground infrastructure. D11 will be the providing the ground capabilities and the associated air-ground constraints.

MA-AFAS concept (D9) is based on the implementation of Air-Ground applications such as data link communication, 4D trajectory negotiation , taxi management, CDTI/ASAS, and precision approach applications.

The scenario are defined for a specific environment and using a set of applications that can be sequentially used during the scenario or may interfere depending on the phase of the flight. The major headings of an Operational Service Environment Definition are : the environment including the airspace structure and the traffic characteristics and the description of each individual operational application.

Within this document the Operating environment description will be provided for the total set of selected applications. However, in the different environment elements, the applications that are relevant will be specified.

From these environment and application descriptions, operational scenario will be established using the various selected application during gate to gate flights.

1.2 Reference documents:

ICAO documents

- Manual of Air Traffic Services Data Link Applications, First Edition – 1999. Doc 9694-AN/955
- Manual of Technical Provisions for the Aeronautical Telecommunication Network (ATN), (Doc 9705/2) 1st edition 1998. (CNS/ATM-1 package - ATN SARPS)
- Annexes to the Convention International Civil Aviation. Annex 6, Operation of Aircraft, 7th edition, incorporating amendments 1-23. July 1998.
- Annexes to the Convention International Civil Aviation. Annex 11, Air Traffic Control Service Flight Information Service Alerting Service. 12th edition, incorporating amendments 1-38. July 1998.
- Procedures for Air Navigation Services. RAC Rules of the Air and Air Traffic Services. (Doc 4444) 13th edition, 1996, incorporating amendments 1-7.
- ICAO SARPS for VDL Amendment 72 to Annex 10, Volume III.
- ICAO - Regional Supplementary Procedures (Doc 7030)
- ICAO - Manual on Implementation of a 300 m (1000 ft) Vertical Separation Minimum between Fl 290 and FL 410 Inclusive (Doc 9574)
- ICAO Document 9426, Air Traffic Services Planning Manual

JAA documents

- TARA

FAA documents:

- Guidelines for design approval of aircraft data communications systems, AC No: 20-140.
- Initial air carrier operational approval for use of digital communication systems, AC No: 120-COM.
- FAA Order 7110.XX

RTCA/EuroCae guidelines:

- RTCA SC189/EuroCae WG53 PSG-1401 rev TBD - "Initial Interoperability Requirements for Baseline 1 ATN ATS Applications".
- RTCA SC189/EuroCae WG53 P/SG2/2 rev 10 "Characteristics of the CNS/ATM Operational Environment for Air Traffic Services (ATS) that Use Data Communications".
- RTCA SC189/EuroCae WG53 P-SG2-21 rev 5 "CNS/ATM Safety Assessment".
- RTCA SC189/EuroCae WG53 P-SG2-25 rev 18 "Guidance for the application of SG2-21 (CNS/ATM Safety Assessment)".
- RTCA SC189/EuroCae WG53 P-PUB-22 rev E "Guidelines for Approval of Provision and Use of Air Traffic Services Supported by Data Communications".
- RTCA SC189/EuroCae WG53 P-PUB-20 rev B "Methods for Operational Environment description and Evaluating Operational environment (Safety assessment and Performance process and allocation)".

EUROCAE guidelines

- "Minimum Aviation Performance Standards for a Global Navigation Satellite System Ground-Based Augmentation System to Support Cat I Operations", EUROCAE ED-95.

Eurocontrol:

EATMS OCD (FCO.ET1.ST07.DEL01 EATCHIP Ed 1.1 04/01/99)

ATM Strategy for 2000+, Issue January 2000.

Operational Requirements For Air/ground Cooperative Air Traffic Services AGC-ORD-01 (issued 3/11/00). This document replaces and supersedes the "Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services", Edition 1.0, 15 January 1998, reference OPR.ET1.ST05.1000-ORD-01-00.

"Initial Evaluation of Limited Delegation of Separation Assurance to the Cockpit", Karim Zeghal, Eric Hoffman, Anne Cloerec, Isabelle Grimaud, Jean-Pierre Nicolaon, SAE/AIAA World Aviation Congress, San Francisco, October 1999

"Evaluation of Delegation of Sequencing Operations to the Flight Crew from a Controller Perspective – Preliminary results", Karim Zeghal, Isabelle Grimaud, Eric Hoffman, SAE/AIAA World Aviation Congress, San Diego, October 2000

"Procedures of delegation from the controller to the pilot", version 2.1, Isabelle Grimaud, Karim Zeghal, Eurocontrol Experimental Centre, November 2000

Others:

ARINC 755-1 Multi Mode Receiver

ARINC 756-2 GNSS Navigation and Landing Unit

Scenario/OSED:

- NUP OED Working draft to be used for MA-AFAS programme
- OED PETAL II, ref. Eatchip OPR.ET1.ST05
- FARADEX WP3: Operational Scenario Identification and Analysis (FARADEX/NLR/WPR/WP3/Issue 2.0 Transport Programme (1994-1998))

ASAS application:

- OCD for CDTI initial applications (RTCA SC186-145)
- CD&R OCD (RTCA SC 186 Version 2.8)
- MOPS ASSAP (RTCA SC186 WG4 Draft 0.6)
- RTCA SC-186, Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B), DO-242.
- “Minimum Aviation Performance Standards for the Local Area Augmentation System” (LAAS) RTCA DO-245
- “The GEARS conflict resolution algorithm”, R.J. Irvine, AIAA Guidance Navigation and Control Conference, Boston, August 1988.

CDTI:

- MOPS (RTCA SC186) RTCA SC-186,
- Guidance for Initial Implementation of Cockpit Display of Traffic Information, DO-243,1998.
- SAE S-7 ARD50083, ARP4101, ARP4102, AS8034

TIS:

NUP: TIS-B service description

FIS:

NUP: FIS-B service description

GRAS:

NUP: GRAS service description

Environment:

Operational Environmental Definition for Baseline 1 Air Traffic Services Maastricht UAC and US NAS (OED BL1.1)”, PETAL-II Project, EUROCONTROL, Jun 21, 2000.

AIP Germany

AIP Italia..

2 Operating environment Characteristics

This document defines the characteristics of the Communications, Navigation, and Surveillance (CNS)/Air Traffic Management (ATM) operational environments for Air Traffic Service (ATS) that uses MA-AFAS applications. The term 'operational environment' is defined here by those characteristics which form the descriptive basis of operations relevant for assessing the safety of flight operations for current conditions or conditions under MA-AFAS services. These services are designed to enable operational objectives that increase capacity while maintaining safety level.
The operational environment characteristics are described under the following items: Operational characteristics, Traffic characteristics, Technical characteristics, Availability characteristics and Volume characteristics.

2.1 Operational Characteristics

2.1.1 ATC means

It is planned that in the year 2007, ATC will be conducted with varying levels of delegation to pilots for the role of separation assurance and traffic management. In Free Flight Airspace (FFAS) full delegation will be applied by 2015.
In the year 2007, the controller-pilot communication via data link will be used for non-time critical ATC communication. Voice will still be used for time critical voice communication between pilots and ATC. It is also planned that other forms of operational data link, such as automatic dependent surveillance broadcast (ADS-B) will be used for information exchange among aircraft and with the ground ATC system.
Due to varying levels of aircraft CNS capabilities, varying complexity and location of the airspace, and varying objectives of airspace users, ATC will be provided both as it is provided today and at higher levels of autonomy by pilots.

2.1.2 Flight phases

The MA-AFAS validation scenario will be established on a gate to gate flight structured in different flight phases. The MA-AFAS selected operational applications (see D13) are related to different parts of the flight plan.

The graphic below depicts for each selected MA-AFAS application the different flight phases during which it may be applied

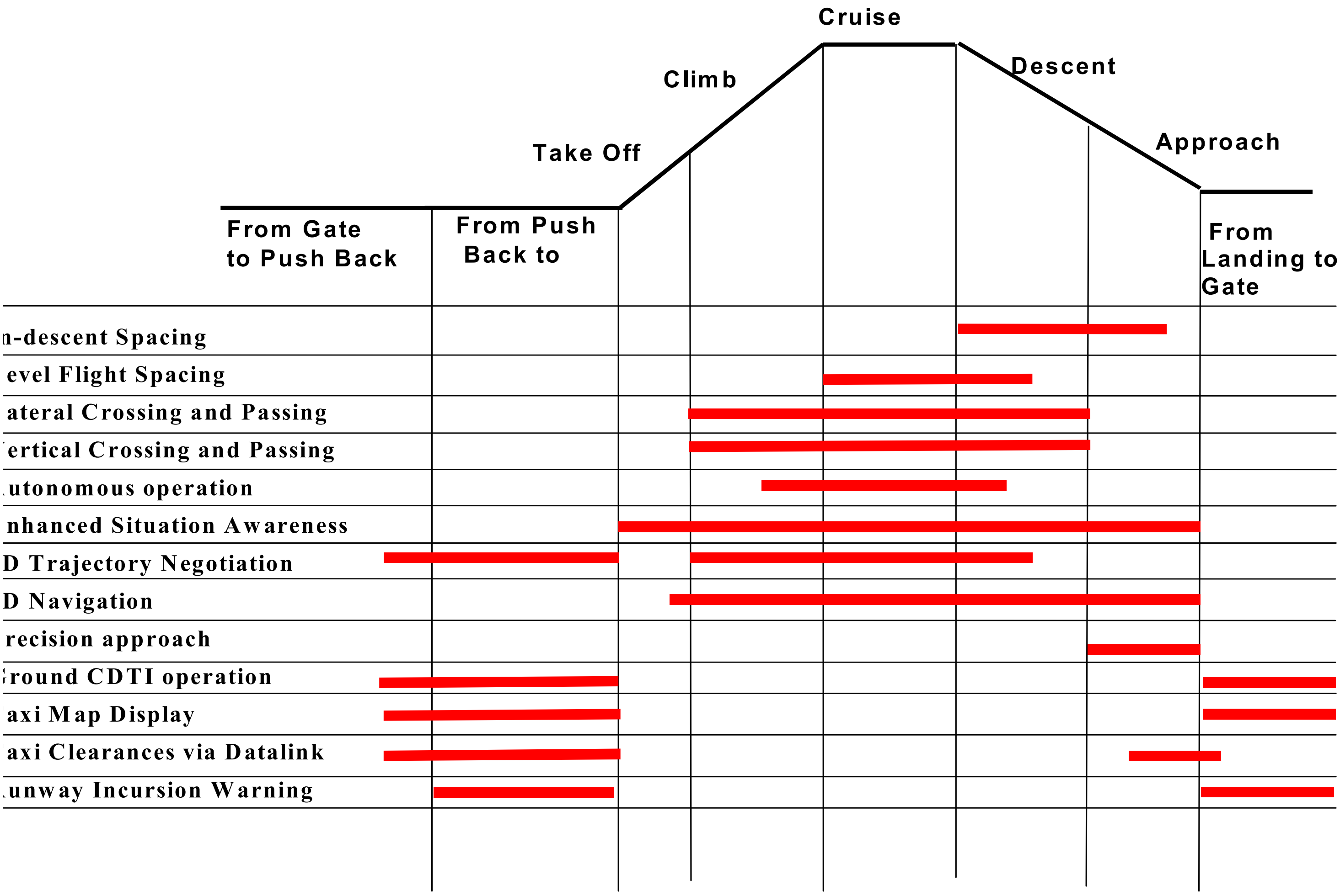


Figure 1 : MA-AFAS operational applications

The gate to gate scenarios (see section 5), from the airborne perspective, will reflect the different MA-AFAS application capabilities along the flight plan. Meanwhile from a controller perspective, different flight phases will also be considered. The scenario will describe the number or percentage of aircraft climbing, descending or in level flight in each of the sectors considered.

The scenario will be based on two different time frames : 2007 and 2015. A scenario describing year 2007 will consider all applications available in this time frame : AOC, Enhanced Situation Awareness, 4D Trajectory Navigation, Level Flight Spacing, In Descent Spacing and Precision Approach. Whereas scenario 2015 will describe all MA-AFAS applications and in particular the autonomous operation.

In parallel to the selected application, communication means will be available. It is assumed as described in section 2.3 that for both time frames, data link will be available including CPDLC services, ADS-B and TIS-B, where voice will be used as a back up or for time critical applications.

It is the scope of the following subsections to describe the environmental characteristics of the flight, including the following:

- The selected flights (FRANKFURT to ROMA) .
- The airspace characteristics
- The traffic characteristics
- The ground infrastructure
- The communication volume

2.1.3 Route Configuration

2.1.3.1 Introduction

This sub-section discusses the route to be flown. First, an overview of the institutional aspects of routing is given. This is followed by details of the actual route chosen, stating the published details of the route configurations for the SID, en-route through each national airspace, and STAR. Finally, evolution of aspects specific to MA-AFAS are discussed.

2.1.3.2 Overview

As recommended in ICAO Annex 11 Chapter 2 §2.9.1, the delineation of airspace, wherein air traffic services are to be provided, should be related to the nature of the route structure and the need for efficient service rather than to national boundaries. Furthermore, FIR regions are generally designed to accommodate the whole of the air route structure (ICAO Annex 11 Chapter 2 §2.9.2.1). Therefore, route configuration constitutes a key parameter both for air traffic operations, and safety and performance assessment of air traffic services.

The design of control areas, airways, and routes is established according to the capabilities of the navigation means appropriate to the level of communications, navigation and air traffic services provided in the airspace concerned. Navigation means encompass both navigation aids (ICAO Annex 11 Chapter 2 §2.9.3.1) and RNP definition (ICAO Annex 11 Chapter 2 §2.7.3).

The “en route airways/route” structure is based upon the principles of ICAO guidance material as contained in the Air Traffic Services Planning Manual (Doc. 9426) as well as associated material applicable to the specific to route type:

- applicable RNP types and associated procedures (ICAO Manual on Required Navigation Performance (RNP) Doc. 9613),
- ATS routes for use by RNAV-equipped aircraft and spacing between routes based on RNP type (ICAO Annex 11 Attachment B),
- ATS routes defined by VOR (ICAO Annex 11 Attachment A),
- special routes established for use by low-level traffic (ICAO Annex 11 Chapter 2 §2.11.2),
- guidance on the establishment of changeover points (ICAO Annex 11 Attachment A).

The standard departure and arrival routes and associated procedures are in accordance with the principles set forth in ICAO Appendix 3.

The route chosen has sufficient ground navigation aid coverage to ensure that RNAV can be performed by a suitably-equipped aircraft. However, in the future, it is likely that these navigation aids will be rationalised, and so it is expected that RNAV will be supported by SBAS.

2.1.3.3. Frankfurt Airport

The following tables describe the physical characteristics of Frankfurt Airport and the intersection take-off distances.

Physical Characteristics										
Desig-nation	**True BRG**	**Length/ Width (m)**	**TORA (m)**	**TODA (m)**	**ASDA (m)**	**LDA (m)**	**THR Elev (ft)**	**Clear Way (m)**	**Strip (m)**	**Strength PCN**
07 L	69º38'	4000x60	4000	4060	4000	4000	329	60	4120x300	74/R/A/W/T
25 R	249º38'	4000x60	4000	4000	4000	4000	364	-	4120x300	74/R/A/W/T
07 R	69º38'	4000x45	4000	4060	4000	4000	328	60	4120x300	74/R/A/W/T
25 L	249º38'	4000x45	4000	4060	4000	4000	362	60	4120x300	74/R/A/W/T
18	179º38'	4000x45	3970	4030	3970	-	325	60	4065x300	90/R/A/W/T

Intersection take-off				
RWY	**TWY**	**TORA (m)**	**TODA (m)**	**ASDA (m)**
07 L	H	2412	2472	2412
	J	3012	3072	3012
	L	3312	3372	3312
	L-EAST	3940	4000	3940
25 R	F	3258	3258	3258
07 R	H	2330	2390	2330
	K	3080	3140	3080
25 L	F	3490	3550	3490
	G	2900	2960	2900
	H	1709	1769	1709
18	N-SOUTH	3885	3945	3885
	A	3800	3860	3800
	C	3450	3510	3450
	S	2735	2795	2735

Threshold Co-ordinates			
Departure End Of Runway	**Threshold**	**Latitude**	**Longitude**
RWY 18		N 49 59 54.531	E 008 31 34.621
RWY 07L	RWY 25R	N 50 02 42.459	E 008 35 13.141
RWY 07R	RWY 25L	N 50 02 24.191	E 008 35 11.513
RWY 25L	RWY 07R	N 50 01 39.161	E 008 32 03.030
RWY 25R	RWY 07L	N 50 01 57.429	E 008 32 04.674

Frankfurt has a Category III Instrument Landing System, to help maintain the rate of approaching aircraft in the event of poor weather.

2.1.3.4. Route Configuration in German Airspace

Frankfurt is a complex airport, and there are a large number of Standard Instrument Departures (SID), the one used being dependent upon the departure runway and route direction. The SID chosen makes use of RNAV, and it links up to a new RNAV route for departures to the south.

The following tables describe the instrument departure procedures and coded routes associated with Frankfurt Airport.

Standard Departure Routes – Instrument (SID)		**RWY 25L/R**
Route	**Climb To**	**Contact**
DAMOR SIX GOLF (**DAMOR 6G**) On RWY track to 5 DME FFM or 800, whichever is later, RT MT 275º (RWY 25L: MT 280º), on R 260 FFM to 3500, RT to TAU (Δ), but no before reaching R 260 FFM; on R 326 TAU to DAMOR (Δ). **GPS/FMS RNAV**:[A800+]-DF 134 (25R)/DF 135 (25L)-DF 033-[A3500+]-TAU-DAMOR.	5000	120.150
ARPE SEVEN GOLF (**ARP 7G**) On RWY track to 5 DME FFM or 800, whichever is later, RT MT 275º (RWY 25L: MT 280º), on R 260 FFM to 3500, RT to TAU (Δ), but no before reaching R 260 FFM; on R 352 TAU to 25 DME TAU, RT, on R 202 ARP to ARP (Δ), **GPS/FMS RNAV**:[A800+]-DF 134 (25R)/DF 135 (25L)-DF 033-[A3500+]-TAU-DF 067-ARP.	5000	
WARBURG EIGHT GOLF (**WRB 8G**) On RWY track to 5 DME FFM or 800, whichever is later, RT MT 275º (RWY 25L: MT 280º), on R 260 FFM to 3500, RT to TAU (Δ), but no before reaching R 260 FFM; RT, on R 026 TAU to WRB (Δ), **GPS/FMS RNAV**:[A800+]-DF 134 (25R)/DF 135 (25L)-DF 033-[A3500+]-TAU-DF 068-WRB.	5000	
GIESSEN SEVEN GOLF (**GIN 7G**) On RWY track to 5 DME FFM or 800, whichever is later, RT MT 275º (RWY 25L: MT 280º), on R 260 FFM to 3500, RT to TAU (Δ), but no before reaching R 260 FFM; on R 048 TAU to GIN (Δ). **GPS/FMS RNAV**:[A800+]-DF 134 (25R)/DF 135 (25L)-DF 033-[A3500+]-TAU-GIN.	5000	
DINKELSBÜHL SEVEN GOLF (**DKB 7G**) On RWY track to 1.5 DME FRD or 800, whichever is later, LT inbound RID to 12 DME RID, LT, on track 120º to KNG(Δ), RT, on R 131 FFM to DKB(Δ). **GPS/FMS RNAV**:[A800+]-DF 034 (25R)/DF 035 (25L)-DF 043-KNG-DKB.	5000	120.425 (at certain times 120.150 may be used)

ANEKI ONE FOXTROT/ONE GOLF (**ANEKI 1F/G**) On RWY track to 1.5 DME FRD or 800, whichever is later, LT on R 358 RID to RID (Δ); on R 185 RID to ANEKI (Δ). **GPS/FMS RNAV**:[A800+]-DF 034 (25R)/DF 035 (25L)-DF 037-RID-ANEKI.	5000	

Route Y 163				
Points	**Initial True Track**	**Dist. (NM)**	**Vertical limits Upper/Lower**	**Directions Odd/Even**
Δ ANEKI 49 19 02 N 08 28 50 E	184.9	15.3	FL 450/ 5000 ft MSL	odd
Δ BADLI 49 03 49 N 08 26 51 E	192.9	16.9	FL 450/ 7000 ft MSL (FL 100)	
Δ PABLA 48 47 19 N 08 21 07 E	193.6	18.4		
Δ HERBI 48 29 27 N 08 14 37 E	170.8	19.5		
Δ NATOR 48 10 12 N 08 19 17 E				

Route UN 850				
Points	**Initial True Track**	**Dist. (NM)**	**Vertical limits Upper/Lower**	**Directions Odd/Even**
Δ BAGOS (UIR BDRY) 54 34 22 N 11 16 12 E	209.0	18.6	FL 450/ FL 250	odd
Michaelsdorf DVOR Δ MIC 54 18 20 N 11 00 19 E	203.0	90.7		
Δ AGATI 52 54 42 N 10 01 44 E		91.0		
Warburg DVOR/DME Δ WRB 51 30 21 N 09 06 39 E	187.8	31.2		
Δ EDEGA 50 59 29 N 08 59 59 E		11.6		
Δ AMETU 50 48 03 N 08 57 27 E		15.6		
Δ SOGMI 50 32 34 N 08 54 09 E		29.5		
Δ BOMBI 50 03 24 N 08 48 01 E		64.4		
Karlsruhe DVOR/DME Δ KRH 48 59 35 N 08 35 03 E	192.1	50.5		
Δ NATOR 48 10 12 N 08 19 17 E	170.8	18.9		

Δ TITIX 47 51 30 N 08 23 48 E		10.3		
TrasadingenDVOR/DME Δ TRA 47 41 22 N 08 26 13 E				

GPS/FMS RNAV Departure Routes			**Frankfurt (Main)**
Way Point List			
Ident	**Latitude**	**Longitude**	**Definition**
DF 033	N 50 01 50.155	E 008 26 48.513	Track 280º/274º - R 260 FFM
DF 034	N 50 01 38.832	E 008 30 49.498	RWY track/5(2) DME FFM(FRD) (RWY 25R)
DF 035	N 50 01 23.343	E 008 30 58.180	RWY track/5(2) DME FFM(FRD) (RWY 25L)
DF 037	N 49 57 57.323	E 008 31 42.440	300º KNG/R 358 RID
DF 038	N 49 58 14.653	E 008 25 11.152	Track 230º/R 240 FFM
DF 039	N 50 03 24.723	E 008 38 13.200	RWY track/FFM (RWY 07L)
DF 040	N 50 03 07.293	E 008 38 14.763	RWY track/FFM (RWY 07R)
DF 043	N 49 58 39.089	E 008 29 47.630	Track 200º/300º KNG
DF 044	N 50 02 52.165	E 008 35 56.351	RWY track/1.5(1.6) DME FFM(FRD) (RWY 07L)
DF 045	N 50 02 36.372	E 008 36 04.615	RWY track/1.5(1.6) DME FFM(FRD) (RWY 07R)
DF 046	N 50 06 12.820	E 008 38 06.789	R 359 – 3 DME FFM
DF 047	N 50 19 13.936	E 008 37 36.852	R 359 FFM/R 288 MTR
DF 048	N 50 38 03.624	E 008 36 53.418	R 359 – 3 DME FFM/R 153 ARP/R 200 WRB
DF 049	N 50 04 21.868	E 008 42 38.570	R 070 – 3 DME FFM/R 203 MTR
DF 050	N 50 00 36.898	E 008 45 06.262	Track 245º/R 194 MTR
DF 051	N 50 03 34.748	E 008 48 36.529	R 087 – 5 DME FFM
DF 052	N 50 04 13.988	E 008 42 28.829	R 070 – 3(6) DME FFM(FRD)
DF 053	N 49 50 28.889	E 008 41 25.869	R 194 MTR/288º KNG
DF 054	N 49 58 45.921	E 008 35 46.694	Track 245º/R 200 FFM
DF 055	N 49 47 04.895	E 008 29 23.362	R 200 FFM/R 276 RID
DF 056	N 49 52 04.965	E 008 32 07.299	R 200 FFM/R 358 RID
DF 057	N 49 47 27.957	E 008 40 20.257	R 194 MTR/R 084 RID
DF 058	N 49 58 00.009	E 008 31 34.979	R 358 RID/300º KNG
DF 059	N 49 56 58.590	E 008 34 25.122	R 202 FFM/300º KNG
DF 060	N 49 52 25.145	E 008 32 05.819	R 358 RID/track 240º
DF 061	N 49 46 54.049	E 008 32 29.382	RID
DF 062	N 49 47 39.005	E 008 19 40.415	Track 245º/R 276 RID
DF 063	N 49 57 10.918	E 008 29 09.767	Track 200º/R 224 FFM
DF 064	N 49 51 44.069	E 008 21 02.234	R 224 FFM/R 304 RID
DF 065	N 49 47 54.195	E 008 15 19.218	R 224 FFM/R 276 RID
DF 066	N 49 48 34.256	E 008 03 56.392	R 276 RID/161º RUD
DF 067	N 50 39 44.548	E 008 03 33.786	R 351 – 25 DME TAU
DF 068	N 50 37 36.208	E 008 26 28.181	R 026 – 25 DME TAU
DF 096	N 49 53 06.669	E 008 11 44.586	R 240 FFM/R 087 KIR
DF 097	N 49 58 46.719	E 008 31 34.614	RWY track/R 224 FFM

2.1.3.5. Route Configuration in Swiss Airspace

Part of the route flies through Swiss Airspace.

TRA	UN850	UP2	290
RIPUS	UN850	UP2	290
GERSA	UN850	UP2	290
ODINA	UM727	EN3	290
SRN	UM727	EN3	290

2.1.3.6. Rome/Ciampino (LIRA) Airport

The following sections provide information on Rome Airport, to be used in the validation scenarios.

2.1.3.6.1 General Information:

REFERENCE POINT: Lat 41° 47’ 55’’ N Lon 12° 35’ 42’’ E
Site: RWY centre
Elevation: 130 M (426 FT)
Aerodrome Reference Temperature: 30.6° C
Transition Altitude: 6000 FT
Aerodrome Operator or Administrative Authority: Italian Air Force, Aeroporti di Roma SpA
Telegraphic Address AFTN: LIRAYDYX
Seasonal availability: All Year

2.1.3.6.2 Runways

RWY	Ref. Point	THR Elev/Coord	TORA (M)	ASDA (M)	TODA (M)	LDA (M)
15	414755N123542E	420FT/414827N123230E	2197	2197	2428	2197
33	414755N123542E	420FT/414726N123604E	2197	2197	2393	2197

Physical Characteristics									
Designation	**True BRG**	**Length/ Width (m)**	**TORA (m)**	**TODA (m)**	**ASDA (m)**	**LDA (m)**	**THR Elev (ft)**	**Clear Way (m)**	**Strip (m)**
15	153º	2197x45	2197	2428	2197	2197	341	231	4120x300
33	333º	2197x45	2197	2393	2197	2197	426	196	4120x300

There are obstacles to the South-East of the airport. The airport is shared civil/military. There is no information on local flying restrictions.
The validation simulation will assume that a GBAS is installed on the airfield to enable Precision Approaches.

2.1.3.6.3 Local Flight Restrictions

RWY 33 landing are prohibited to civil aircraft on HJ ± 30 IMC only and HN ± 30.
HEL LDG/TKOF must be performed on RWY.
General Aviation aircraft shall contact Aeroporti di Roma at least 20 min. before ETA, frequency 131.625 MHz, call sign: CIAMPINO GENERAL AVIATION, HR 0500/2130 (0400/2030), languages: IT/EN.

2.1.3.6.4 Pre-flight altimeter check points and elevation

THR 15: M 103.9 (341 FT)

THR 33: M 129.8 (426 FT)

2.1.3.6.5 STARs

NAME	RWY	1°Point/Alt	2°Point/Alt	3°Point/Alt	4°Point/Alt
BOL1A	15/33	BOL/110	TIBER/90	URB/30	
TEA1A	15/33	TEA/110	PEMAR/100	GUI/100	URB/55
PEMAR1A	15/33	PEMAR/120	GUI/100		URB/55
PNZ1A	15/33	PNZ/100	CIRCE/100	LAT/100	CIA/60
ROTUN1A	15/33	ROTUN/50	ESINO/50	OST/50	URB/30
TURMO1A	15/33	TURMO/50	ESINO/50	OST/50	URB/30
VALMA1A	15/33	VALMA/85	OST/50		URB/30
ELB1A	15/33	ELB/110	GILIO/110	BOL/110	URB/30
GRO1A	15/33	GRO/180	CMP/50		URB/30
BOL2A*	15/33	BOL/90	CMP/50		URB/30
PEMAR2A*	15/33	PEMAR/120	CIA/45		URB/30
TEA2A*	15/33	TEA/100	FRS/100	CIA/60	URB/30
ROTUN2A*	15/33	ROTUN/50	OST/50		URB/30
ESINO2A	15/33	ESINO/85	OST/50		URB/30
VALMA2A*	15/33	VALMA/50	OST/50		URB/30

Note 1: Levels below 70 are hundreds feet of altitude (Transition Alt. 6000FT)

Note 2: STARs followed by asterisk are “ATC discretion”

2.1.3.6.6 SIDs

NAME	RWY	1°Point/Alt	2°Point/Alt	3°Point/Alt	4°Point/Alt	CTRL
OST5A	15	R105 OST/30			OST/60	
OST5B	15	R088 OST/30			OST/50	
PEMAR5A	15	PRA/ 60	R349 LAT/80		PEMAR/12 0	
OST5C	15	MAGLI/30	AKILI/40		OST/50	
URB5A	15	URB/30			URB/30	
PRA5B	33	CIA/20			PRA/30	
OST5D	33	CIA/20			OST/50	
URB5B	33	CIA/20			URB/30	

Note: All the Flight Levels below 70 are hundreds feet of altitude

2.1.3.6.7 Holdings

FIX name	Coordinates	Inbound Track	Outb Time	Orientation (L/R)	MHA/L

ALG VOR/TAC	403739N081440E	045°		left	4000FT
BOKNA	415148N125724E	300°		right	FL100
BOL VOR/TAC	423704N120256E	153°		right	6000FT
CIA NDB	415151N123339E	330°		right	4500FT
CMP VOR/DME	420723N122254E	198°		right	4000FT
ELB VOR/TAC	424348N102346E	152°		right	7000FT
ESINO	412306N114742E	038°		right	6000FT
FN LO	415440N121358E	162°		left	2000FT
FRS LO	413835N131723E	308°		right	FL100
FW LO	415249N121156E	162°		left	2000FT
GODIL	434318N110542E	041°		right	3000FT
JESSY	432924N101148E	037°		left	3000FT
LAT VOR/DME	413226N125508E	268°		right	FL90
OST VOR/DME	414811N121416E	167°		left	3000FT
PIS VOR/DME	434035N102328E	230°		left	5000FT
PNZ VOR/TAC	405440N125727E	102°		right	4000FT
PRA L	414045N122711E	295°		left	4000FT
PRT VOR/DME	434836N111206E	212°		right	5500FT
RATIR	414030N122700E	308°		left	4000FT
TAQ VOR/DME	421252N114359E	141°		left	6000FT
TEA VOR/DME	411745N135814E	324°		right	5000FT
TOSCO	433548N105048E	050°		right	5000FT
VALMA	413436N112518E	069°		left	6000FT
VITER	422812N120500E	170°		left	6000FT

2.1.3.7. Route Configuration in Italian airspace

Roma TMA includes the Roma/Fiumicino, Roma/Ciampino, Roma/Urbe and Napoli aerodromes. Moreover, the Viterbo Aerodrome and the Marina di Campo Aerodrome are subject to special rules.
The Area Control Service is provided by Roma ACC.
AIP Italia (RAC 4-2-2.7) shows a STAR that is available at ATC discretion from the CMP NDB/VOR/DME to NDB Urbe, to the north of Ciampino. This STAR shows an MEA of 3000, and a slight change in track from the previous route from 153 degrees to 155 degrees. The hold at CMP is at 4000 feet after passing through Danger Areas R53A and R41.
The two tables below show the part of the chosen route that is in Italian airspace.

Route UM 727					
Points	**Mag. Track**	**Dist. (NM)**	**Vertical limits Upper/Lower**	**Directions Odd/Even**	
▲Saronno VOR/DME SRN 45 38 42 N 09 01 19 E	132/313	73	FL 460/ FL 245	250	

▲Parma NDB PAR 44 49 18 N 10 17 38 E	147/327	56	FL 460/ FL 195	210	
▲Firenze VORTAC FRZ 44 01 38 N 11 00 13 E Milano ACC/Roma ACC	151/331	55			
Δ AMTEL 43 13 12 N 11 36 30 E		41			
▲Bolsena VORTAC BOL 42 37 04 N 12 02 56 E					

Route UA 41					
Points	**Mag. Track**	**Dist. (NM)**	**Vertical limits Upper/Lower**	**Directions Odd/Even**	
▲Dijon VORTAC DIJ 47 16 15 N 05 05 52 E	121/303	140			
Δ PUNSA 46 04 42 N 08 01 36 E		17	FL 460/ FL 195	210	200
▲ARLES 45 55 48 N 08 22 30 E GenèveACC/MilanoACC		32			
▲Saronno VOR/DME SRN 45 38 42 N 09 01 19 E	132/313	73	FL 460/ FL 245	250	260
▲Parma NDB PAR 44 49 18 N 10 17 38 E	176/356	39	FL 460/ FL 195	210	200
▲BEROK 44 09 54 N 10 21 06 E		15			
▲SIPLO 43 55 30 N 10 22 12 E Milano ACC/Roma ACC		15			
▲Pisa VOR/DME PIS 43 40 35 N 10 23 28 E	154/334	26	FL 460/ FL 245	250	
▲MAREL 43 16 54 N 10 39 06 E		38			
▲Grosseto NDB GRO 42 42 17 N 11 01 32 E	132/313	43	FL 460/ FL 195	210	
▲Tarquinia VOR/DME TAQ 42 12 52 N 11 43 59 E					

2.1.3.8. Route Frankfurt-Rome (Ciampino)

The following table provides routes between Frankfurt and Rome, including sector identifiers and flight levels.

Time	Navaid	Route	Sector	FL
9H49	RID	SID?	SR6E	
9H55	ANEKI	Y163	SR6E	158
9H57	BADLI	Y163	SR6E	198
9H59	PABLA	Y163	DP1	241
10H02	HERBI	Y163	SL2	283
10H04	NATOR	UN850	SL2	290
10H07	TITIX	UN850	UP2	290
10H08	TRA	UN850	UP2	290
10H12	RIPUS	UN850	UP2	290
10H13	GERSA	UN850	UP2	290
10H21	ODINA	UM727	EN3	290
10H25	SRN	UM727	EN3	290
10H34	PAR	UA41	ES3	290
10H40	BEROK	UA41	ES3	290
10H41	SIPLO	UA41	NE2	290
10H43	PIS	UA41	NE2	290
10H47	MAREL	UA41	NE2	290
10H52	GRO	LIRAGRO11	UNR	290
11H02	CMP	LIRAGRO11	TNR	90
11H06	URB	LIRAGRO11	ARR	41
11H06	LIRA	LIRAGRO11	ARR	0

2.1.3.9. Other Routes

A1/UA1	COORDINATES	Mag. Track	Vertical Limits	Remarks
SPR VOR/DME	462812N/062656E	148/328		
BANKO	454912N/070318E	148/328	460/185	
ADISO	453330N/071736E	148/328		
TOP VOR/DME (TOP/NDB)	445529N/075143E (445527N/075139E)	148/328	460/85	
LAGEN	442336N082954E	140/321		
ANAKI	441206E084330E	140/321		
UNITA	435642N090130E	140/321		
KAFEE	434800E/091130E	140/321		
KONER	433018N093148E	140/321	460/65	

MAURO	431118N095312E	140/321		
ELB/VORTAC (ELB/NDB)	424348N102346E (424355N102339E)	132/313	460/75	
GILIO	422200N105536E	132/313		
MEDAL	420312N112236E	132/313		
RAVAL	414818N114336E	132/313		
TORLI	413548N120106E	132/313		
ELVIN	412936N120942E	132/313		
RIFFI	411330N123154E	132/313		
PNZ/VORTAC (PNZ/NDB)	405440N125727E (405438N125723E)	132/313		

UA35/A35	COORDINATES	Mag. Track	Vertical Limits	Remarks
SPR VOR/DME	462812N062656E	138/319	460/245	
AOSTA	454748N072042E	138/319		
TONDA	450636N081348E	138/319		
GENVOR/DME (GEN/NDB)	442525N/090457E (442523N090500E)	150/331	460/195	
SPEZI	434636N093542E	150/331	460/85	
BELEL	433312N094606E	150/331		
NORNI	431642N095848E	150/331	460/65	
ELB/VORTAC (ELB/NDB)	424348N102346E (424355N102339E)	150/331		

UG32/G32	COORDINATES	Mag. Track	Vertical Limits	Remarks
PAS VOR/DME	460954N060002E	134/315		
ROCCA	454318N064048E	134/315	460/175	
MEGEV	452848N070242E	134/315		
TOPVOR/DME (TOP/NDB)	445529N075143E (445527N075139E)			

UB25/B25	COORDINATES	Mag. Track	Vertical Limits	Remarks
RENEE	451400N064942E	113/294	460/195	
30 NM W TOP	450712N071242E			Geneve/Milano ACC
TOP VOR/DME (TOP/NDB)	445529N075143E (445527N075139E)	120/300	460/85	
GEN VOR/DME	442525E090457E	106/286		

(GEN/NDB)	(442523N090500E)			
KALMO	441918N093536E		460/105	
BEROK	440954N102106E			
FRZ VOR/TAC	440136N110013E	103/284		
VALEN	435612N113200E			
BAGNO	435324N114806E			

UA9/A9	COORDINATES	Mag. Track	Vertical Limits	Remarks
TRA VOR/DME	474127N082617E	169/349		
CANNE (MKR)	461004N085256E		460/125	Zurich/Milan ACC
SRN VOR/DME (SRN/ L)	453842N090119E (453845N090125E)	183/003	460/105	
VOG VOR/DME (VOG/NDB)	445750N085814E (445747N085821E)	172/352		
GEN VOR/DME (GEN/NDB)	442525N090457E (442523N090500E)	185/005		
UNITA	435642N090130E			
TORTU	432306N085730E			
AJO VOR/DME	414614N084630E	176/356		

UB4/B4	COORDINATES	Mag. Track	Vertical Limits	Remarks
SPR VOR/DME	462812N062656E	138/318		
AOSTA	454748/072042E	098/278	460/175	
TERSI	454712N072736E			Geneve/Milano ACC
OMETO	454412N080236E		460/145	
BAVMI	454212N082430E		460/105	
SRN VOR/DME (SRN/ L)	453842N090119E (453845N090125E)	090/271		
ELTAR	453848N103742E			Milano/Padova ACC
VIC VOR/DME	453812N114036E	142/322		

UG375/ G375	COORDINATES	Mag. Track	Vertical Limits	Remarks
LUSIL	460236N100700E	221/041	400/245	
TZO VOR/DME (TZO/NDB)	453330N093030E (453328N093035E)	213/032		
VOGVOR/DME (VOG/NDB)	445750N085814E (445747N085821E)	211/031	460/85	
LAGEN	442336N081317E			
ABN NDB	440319N081317E			

UA12/A12	COORDINATES	Mag. Track	Vertical Limits	Remarks
LUTOR	442918N112136E		460/95	
FRZ/ VORTAC	440136N110013E	199/018		Padova/ Roma ACC
GINAR	433754N104900E		460/105	
MAREL	431654N103906E			
ELB/VORTAC (ELB/NDB)	424348N102346E (424355N102339E)	163/343	460/100	
PODOX	421636N103436E			
AGASA	414806N104548E			
TINTO	412554N105424E			
ROXAN	404830N111018E			
VELEX	395800N112730E	145/325		
PAL VOR/DME	380154N131038E			

UA124/A124	COORDINATES	Mag. Track	Vertical Limits	Remarks
ELB VOR/TAC (ELB/NDB)	424348N102346E (424355N102339E)	200/020	400/100	
GILET	422230N101306E			
BEKOS	414736N095600E			
TALIN	410218N093418E			
SME VOR/DME (SME/NDB)	405322N093005E (405347N093049E)	195/015		
KOLUS	404306N092630E			
BAREN	402454N092006E			
COP	401930N091812E			
KOVAS	393842N090412E			

UR16/R16	COORDINATES	Mag. Track	Vertical Limits	Remarks
NIZ VOR/DME	434614N071518E	114/295		
GIRAG	425942N093748E		460/75	Marseille/Roma ACC
ELB VOR/TAC (ELB/NDB)	424348N093748E (424355N102339E)			

UA3/A3	COORDINATES	Mag. Track	Vertical Limits	Remarks
STP VOR/DME	431310N063609E	100/281		
CAPCO	425048N093430E		460/85	Marseille/Roma ACC
ELB VOR/TAC (ELB/NDB)	424348N093748E (424355N102339E)			

UR160/R160	COORDINATES	Mag. Track	Vertical Limits	Remarks
OST VOR (OST/NDB)	414811N121416E (414816N121412E)	291/110 291/119	460/65	
MEDAL	420312N112236E			
ROTIR	421306N104706E			
PODOX	421636N103436E			
GILET	422230N101306E			
BTA VOR	423428N092833E			Roma/Marseille ACC

UA26/A26	COORDINATES	Mag. Track	Vertical Limits	Remarks
BTA VOR	423428N092833E	077/257	460/85	Marseille/Roma ACC
ELB VOR/TAC (ELB NDB)	424348N093748E (424355N102339E)	093/273	460/175	
GRO NDB	424217N110132E	119/300		
ROSKI	424218N110130E			
CMP VOR/DME (CMP NDB)	420723N122254E (420728N122250E)			

UA41/A41	COORDINATES	Mag. Track	Vertical Limits	Remarks
DIJ VOR/TAC	471615N050552E	121/303		
ARLES	455548N082230E		460/195	
SRN VOR/DME (SRN/L)	453842N090119E (453845N090125E)	132/313	460/115	
PAR NDB	444918N101738E	176/356		
BEROK	440954N102106E			
SIPLO	435530N102328E			
PIS VOR/DME	434035N102328E	154/334		
MAREL	431654N110132E			
GRO NDB	424217N110130E	132/313	460/175	
ROSKI	424218N110130E			
TAQ VOR/DME	421252N114359E			

UG25/G25	COORDINATES	Mag. Track	Vertical Limits	Remarks
OST VOR/DME	414811N121416E	270/088	460/65	
MAMAR	414812N110548E			
AGASA	414806N104548E			
BEKOS	414736N095600E			

IDORI	414724N094500E			
AJO VOR/DME	414614N084630E			

UG23/G23	COORDINATES	Mag. Track	Vertical Limits	Remarks
GOBIS	404430N072242E		460/85	Marseille/Roma ACC
ALG VOR/TAC	403739N081440E	067/249		
MINKA	404906N085118E			
TALIN	410218N093418E			
BATOX	411248N100924E			
TINTO	412554N105442E			
VALMA	413436N112518E			
OST VOR/DME (OST/NDB)	414811N121416E (414816N121412E)	065/246	460/115	
PEMAR	420148N125512E			
ANEDA	421612N133954E			Roma/Brindisi ACC
PES VOR/DME	422607N141104E	054/235		

UG14/G14	COORDINATES	Mag. Track	Vertical Limits	Remarks
OST VOR/DME (OST/NDB)	414811N121416E (414816N121412E)	218/037	460/85	
ESINO	412306N114742E			
ROXAN	404830N111018E			
ALEDI	393636N095936E			
CAR VOR/DME	390639N093030E	220/040		
SARDI	383124N085248E			

UB32/B32	COORDINATES	Mag. Track	Vertical Limits	Remarks
OST VOR/DME (OST/NDB)	414811N121416E (414816N121412E)	176/356	460/100	
ROTUN	405300N121818E			
COP	400818N122306E			
CORAD	394524N122306E			
GIANO	385206N122648E	220/040		
INDOR	373148N105730E			Roma/Tunis ACC
TUC VOR/DME	365118N101404E			

UA14/A14	COORDINATES	Mag. Track	Vertical Limits	Remarks
CANNE MKR	461004N085256E	145/325	460/125	Zurich/Milano ACC
TZO VOR/DME	453330N093030E	143/323	460/85	
PAR NDB	444918N101738E	147/327		
LUPOS	443018N103454E		460/105	
FRZ VOR/TAC	440136N110013E	151/331		
AMTEL	431312N113630E			
BOL VOR/TAC (BOL/NDB)	423704N120256E (423701N120307E)	131/312		
PEMAR	420148N125512E			
TEA VOR/DME	411745N135814E	100/282		
EKTOL	410630N151018E			Roma/Brindisi ACC

UG7/G7	COORDINATES	Mag. Track	Vertical Limits	Remarks
NIZ VOR/DME	434614N071518E	068/249	460/105	
KEPPO	435524N074612E			Marseille/Milano ACC
ABN/NDB	440319N081317E	059/240		
GEN VOR (GEN/NDB)	442525N090457E (442523N090500E)	085/266 085/266		
GOLAS	442718N093700E			
LUPOS	443018N103454E	082/262		
BOA VOR (BOA/NDB)	443211N103454E (443400N111202E)			

UA15/A15	COORDINATES	Mag. Track	Vertical Limits	Remarks
LEONN	431742N130212E	046/226		
KATAR	430306N124042E			
BOL VOR/TAC	423704N120256E	170/350	460/95	
OST VOR/DME	414811N121416E		460/195	
TURMO	405142N115000E			
VELEX	395800N112730E			

UN851	COORDINATES	Mag Track	Vertical Limits	Remarks
ABENA	461018N090618E	186/006	460/195	Zurich/Milano ACC
SRN VOR/DME	453842N 090119E	183/003		
VOG VOR/DME	445750N 085814E	172/352		
GEN VOR/DME	442525N 090457E	185/005		

TORTU	432306N 085730E			Milano/Marseille ACC
OMEDA	421944N 082143E			

UN851A	COORDINATES	Mag. Track	Vertical Limits	Remarks
OGERO	461036N085806E	176/356	460/195	
SRN VOR/DME	453842N 090119E	183/003		

UA144	COORDINATES	Mag. Track	Vertical Limits	Remarks
ZUE VOR	473537N084908E	167/347		
HANNY	461230N091736E		460/195	Zurich/Milano ACC
TZO VOR/DME	453330N093030E			

UA98	COORDINATES	Mag. Track	Vertical Limits	Remarks
ZUE VOR	473537N084908E	176/356		
OGERO	461036N085806E		460/195	
SRN VOR/DME	453842N 090119E			

UN850	COORDINATES	Mag. Track	Vertical Limits	Remarks
ODINA	460706N084512E	158/339	460/195	Zurich/Milano ACC
SRN VOR/DME	453842N 090119E	183/003		
VOG VOR/DME	445750N 085814E	172/352		
GEN VOR/DME	442525N 090457E	185/005		
TORTU	432306N 085730E			Milano/Marseille ACC
SODRI	430047N082219E			

UR7	COORDINATES	Mag. Track	Vertical Limits	Remarks
HOC VOR	472805N073959E	153/334		
BERIS	460630N084112E		460/195	Zurich/Milano ACC
SRN VOR/DME	453842N 090119E			

UM872/UB372	COORDINATES	Mag. Track	Vertical Limits	Remarks
SPR VOR/DME	462812N 062656E	124/304		
CERVI	455812N 073242E		460/245	Genève/Milano ACC
OMETO	454412N 080236E			
FRZ / VORTAC	440136N 110013E			

BAGNO	435324N 114806E			

UM729	COORDINATES	Mag. Track	Vertical Limits	Remarks
SPR VOR/DME	462812N 062656E	138/319		
AOSTA	454748N 072042E		460/245	
TONDA	450636N 081348E			
GEN VOR/DME	442525N 090457E	150/331	460/195	
SPEZI	434636N 093542E			
BELEL	433312N 094606E			Milano/Roma ACC
NORNI	431642N 095848E			
ELBA / VORTAC	424348N 102346	132/313		
GILIO	422200N 105536E			
MEDAL	420312N 112236E			
TORLI	413548N 120106E			
PNZ/ VORTAC	405440N 125727E	127/309		

UM727	COORDINATES	Mag. Track	Vertical Limits	Remarks
SRN VOR/DME	453842N 090119E	132/313	460/245	
PAR NDB	444918N 101738E	147/327	460/195	
FRZ VOR/TAC	440136N 110013E	151/331		Milano/Roma ACC
AMTEL	431312N 113630E			
BOL VOR/TAC	423704N 120256E			

UW95	COORDINATES	Mag. Track	Vertical Limits	Remarks
SRN VOR/DME	453842N 090119E	124/305	460/285	
SOSPI	450618N 100906E			Milano/Padova ACC
ODENA	444424N 105318E			
BOA VOR/DME	443211N 111727E	134/315		

UM985	COORDINATES	Mag. Track	Vertical Limits	Remarks
VOG VOR/DME	445750N 085814E	032/213	460/245	
TZO VOR/DME	453330N 093030E	041/221	400/245	
LUSIL	460236N 100700E	062/243	400/195	Milano/Padova ACC
GIGGI	461224N 103548E			

UL612	COORDINATES	Mag. Track	Vertical Limits	Remarks

PAS VOR/DME	460954N 060002E	104/285		
BIBAN	455536N 072706E		460/300	
SRN VOR/DME	453842N 090119E	090/271		
ELTAR	453848N 103742E			Milano/Padova ACC
ADOSA	453800N 110000E	121/302		

UM995	COORDINATES	Mag. Track	Vertical Limits	Remarks
GIGGI	461224N 103548E			
LUSIL	460236N 100700E		400/195	Padova/Milano ACC
SRN VOR/DME	453842N 090119E			

UG37	COORDINATES	Mag. Track	Vertical Limits	Remarks
SRN VOR/DME	453842N 090119E	062/243	400/195	
LUSIL	460236N 100700E			Milano/Padova ACC
GIGGI	461224N 103548E			

UM730	COORDINATES	Mag. Track	Vertical Limits	Remarks
GEN VOR/DME	442525N 090457E	106/286		
BEROK	440954N 102106E	176/356		
SIPLO	435530N 102212E			Milano/Roma ACC
PIS VOR/DME	434035N 102328E			

UM726	COORDINATES	Mag. Track	Vertical Limits	Remarks
BAGNO	435324N 114806N			
DENAL	433030N 115236E			Padova/Roma ACC
BOLSENA VORTAC	423704N 120256E	170/350		
OST VOR/DME	414811N 121416E	176/356		
ROTUN	405300N 121818E			

UM728	**COORDINATES**	**Mag. Track**	**Vertical Limits**	**Remarks**
BTA VOR	423428N 092833E	110/290		
KISTO	421948N 102300E	134/316	460/245	
MAMAR	414812N 110548E			

UW90	**COORDINATES**	**Mag. Track**	**Vertical Limits**	**Remarks**
FER NDB	444850N 113700E	171/351	460285	

PELEG	441342N 114406E			
BAGNO	435324N 114806E			
DENAL	433030N 115236E			Padova/Roma ACC
BOLSENA VORTAC	423704N 120256E			

2.1.3.10 Comments on route

Departure separation minima at Frankfurt are determined by wake vortex effects.
The chosen SID for departing Frankfurt is a GPS/FMS Overlay.
The route chosen makes use of a new uni-directional route (ANEKI-TRA) to the south of Frankfurt. This route makes use of the capabilities of RNAV, as it is not predicated on terrestrial navaids (see discussion on "RNAV in the TMA" below).

For the remainder of the route, it will be possible for MA-AFAS to validate the benefit of a User Preferred Trajectory for the entire route (see discussion on "Free Routing" below).
For MA-AFAS simulation purposes, it is proposed that a GBAS approach procedure will be designed, subject to existing obstacle survey data being made available. This approach will be "straight-in" ILS-lookalike. Thus there will be a need to manoeuvre from the end of the published route ("CMP" NDB), in order to "capture" the "glideslope". This will be done using the RNAV capabilities of the FMS, in order to create a "curved approach". This GBAS installation would enable precision approaches for both runway ends, and would possibly enable precision approaches for all airports in the region.

MA-AFAS may also validate benefits of SBAS, which will provide accurate guidance through all phases of flight (thus enabling RNAV in the TMA), and may provide an approach capability where previously there was not one.
The part of the route that is in Swiss airspace simply links the two German and Italian route descriptions.

2.1.3.11 2005

2.1.3.11.1 Free-Routing

In the near future, there is likely to be more opportunity for aircraft to take advantage of free-routing airspace. From the EUROCONTROL OCD, free-routing operations can be seen as a development of the current practice of allowing flights to take up direct routing. Aircraft will fly their own user-preferred trajectories (UPT) (subject to any overriding airspace restrictions) outside the structured routes but in a ' known' environment (their identity, position and intentions are known). ATC intervention will be by exception. The development of automated support systems in the air and on the ground, coupled to new procedures and working arrangements in ATM, will permit the use of free-routing in MAS and so provide significant benefits in flight economy and flexibility for users. The best trajectory between the same two places may change from day-to-day because of changing airspace restrictions, the differing priorities of the aircraft and by the vagaries of the weather and other traffic. Traffic flows on a day-to-day basis will be broadly similar, likely congestion or confliction points will be determined as data on flight plans are analysed and collated with the Meteorological data from ground station forecasts and in-flight now-casts (using automated support tools). Centre supervisors will then be able to implement the best sectorisation plan to match the traffic pattern and to optimise sector loading or to adopt control operations on a flight-by-flight basis.

2.1.3.11.2 Overlay Approaches

Overlay Approaches, where RNAV equipment is used to fly a conventional approach, are currently being flown in some TMA. However, the EUROCONTROL TARA sub group does not encourage their use, as track keeping accuracy is not consistent and can be aircraft/FMS/database dependent. This aspects will be taken into account when true RNAV procedures, preferred for MA-AFAS, are designed.

2.1.3.11.3 RNAV in the TMA

This timeframe will also see the beginning of the use of RNAV in the TMA. This will also provide major benefits, such as:

- More accurate track-keeping (of SIDs and STARs) when the procedure designer takes the aircraft/FMS/database dependencies into account. Aircraft flying the requested tracks more consistently leads to controllers being able to reduce separation, with some of the unpredictability having been removed. As well as the potential gain in airspace capacity, RNAV routes can reduce fuel burn leading to cost savings and reduced emission as well as the ability to avoid overflying designated noise sensitive areas intended to be avoided.
- New approaches can be designed that are more efficient, improving avoidance of dangerous terrain, avoid other traffic in the TMA, and are more environmentally-sensitive.

Use of RNAV in the TMA is predicated on aircraft being equipped with higher performance navigation equipment than is currently mandated (B-RNAV). It is unlikely that the high performance navigation equipment, which could be either augmented GNSS or multi-DME, will be mandated across Europe. It is expected that it will be adopted on a TMA by TMA basis, or possibly state by state. Its ability to maintain current traffic levels is also predicated upon the development of new arrival and departure management tools.

2.1.3.12 2015

2.1.3.12.1 Free Flight Airspace

In this timeframe, equippage with ADS-B may mean that some of MAS will become FFAS, by permitting full delegation of separation to pilots. This will remove any remaining restrictions to User Preferred Trajectories. The characteristics of this airspace, and its entry and exit points, need to be defined.

2.1.4 Air-traffic Complexity

2.1.4.1. Aerodromes

2.1.4.1.1 Frankfurt

The Aerodrome Chart in AIP Germany shows Frankfurt to be a complex airport, having parallel and intersecting runways. The AIP also shows a considerable number of SIDs. Significant benefit may be derived from the publication of new RNAV SIDs resulting in more accurate track-keeping than the existing procedures.

Frankfurt handles a variety of traffic, and so the AIP gives considerable guidance on air traffic complexity around Frankfurt.

The operation of heavier aircraft will cause increased wake turbulence which may constitute considerable hazards to other aircraft, particularly if aircraft follow heavier aircraft during approach or departure, or if they cross the flight paths of heavier aircraft at the same altitude or with a vertical distance of less than 1000 ft (300m) below this altitude.

Aircraft are classified into the following wake turbulence categories

- HEAVY maximum certificated take-off mass of 136000 kg or more,
- MEDIUM maximum certificated take-off mass of less than 136000 kg and more than 7000 kg,
- LIGHT maximum certificated take-off mass of 7000 kg or less.

Aircraft of type B757 are grouped into the category HEAVY because of their wake turbulence characteristics. Separation in front and behind these aircraft will be provided according to the criteria for wake turbulence separation minima for aircraft of the category HEAVY.

A minimum of two minutes is applied if an aircraft of the category LIGHT or MEDIUM takes off behind an aircraft of the category HEAVY and/or an aircraft of the category LIGHT behind an aircraft of the category MEDIUM when using

- the same RWY, or

- parallel RWYs separated by less than 760 m, or
- parallel RWYs separated by at least 760 m if the expected flight path of the following aircraft crosses the flight path of the preceding aircraft at the same altitude or less than 1000 ft (300 m) bellow, or
- crossing RWYs if the expected flight path of the following aircraft crosses the flight path of the preceding aircraft at the same altitude or less than 1000 ft (300 m) below.

A minimum of three minutes is applied between an aircraft of the category LIGHT or MEDIUM which takes off behind an aircraft of the category HEAVY and/or an aircraft of the category LIGHT which takes off behind an aircraft of the category MEDIUM from

- an intersection on the same RWY, or
- an intersection on a parallel RWY with a distance of less than 760 m.

A minimum of two minutes is applied between an aircraft of the category LIGHT or MEDIUM and an aircraft of the category HEAVY and/or between an aircraft of the category LIGHT and an aircraft of the category MEDIUM when operating on a RWY with a displaced THR if

- an aircraft of the category LIGHT or MEDIUM takes off behind an arriving aircraft of the category HEAVY or
- an aircraft of the category LIGHT takes off behind an arriving aircraft of the category MEDIUM, or
- an aircraft of the category LIGHT or MEDIUM lands behind a departing aircraft of the category HEAVY if the expected flight paths cross, or
- an aircraft of the category LIGHT lands behind a departing aircraft of the category MEDIUM if the expected flight paths cross.

A minimum of two minutes is applied between an aircraft of the category LIGHT or MEDIUM and an aircraft of the category HEAVY and/or between an aircraft of the category LIGHT and an aircraft of the category MEDIUM if the heavier aircraft has performed a low approach or a missed approach and the lighter aircraft

- uses a RWY in the opposite direction for take-off, or
- lands in the opposite direction on the same RWY or on a parallel RWY separated by less than 760m.

In order to guarantee a smooth and continuous flow of traffic, departures into an eastern, southern and western direction on the parallel RWY system will be subordinated to arrivals.
For optimal utilization of the RWY system, especially in the case of an increased volume of inbound traffic, the preferred take-off direction for landing direction 25, shall be

- RWY 25R will preferably be assigned to departures in a NW, N and NE direction (with the respective Standard Departure Route), and
- RWY 18 will generally be assigned to departures in a W, SW, S and SE direction (with the respective Standard Departure Route), provided that the tail wind component for RWY 18 is not greater than 15 KT.

Respect to the preferred take-off direction for landing direction 07, the RWY nearest for departure will be assigned. Dependent on the traffic volume, deviations may be made from this rule in order to guarantee a smooth and continuous flow of traffic.

- RWY 07 will preferably be assigned to departures into a NW, N, NE and E direction,
- RWY 18 will generally be assigned to departures into a W, SW, S and SE direction, provided that the tail wind component for RWY 18 is not greater than 15 KT.

If the tail wind component for RWY 18 exceeds 10 knots, this will be announced by ATIS. Pilots-in-command, unable to accept the greater tail wind component, are requested to advise ATC at the same time as the request for start-up clearance.
Departing aircraft shall be ready for take-off at the RWY, 5 minutes prior to commencement of their SLOT at the earliest, and at the CTOT at the latest. Pilots-in-command, who became aware that their prescribed SLOT cannot be adhered to, shall apply for a new SLOT via their airline in good time. In order to adhere to the SLOT times and to optimize RWY capacity, TWR may change the order of departures.
Landing direction 25 will preferably be assigned to landing aircraft, provided the tail wind component does not exceed 5 KT. However, the landing direction will be changed, even if the tail wind component is less than 5 KT, if braking action on the runway is impaired by ice, snow, slush, etc.

2.1.4.1.1.1 High Intensity RWY Operation
ATS will be able to guide aircraft on final using minimum radar separation only if pilots leave the RWY quickly. This guarantees optimal RWY utilization and minimizes the danger of a missed approach.
In order to reduce RWY Occupancy Times, pilots shall apply the following procedures.
The RWYs shall, as a rule, be left via the existing high-speed turn-offs. Pilots-in-command should prepare their landings so as to be able to leave the RWYs via the high-speed turn-off in accordance with the following table when RWY conditions permit (in the table, the distance to turn-off is the distance from threshold of the respective RWY to turn-off intersection).

Preferred turn-off								
Class	**RWY 07L**		**RWY 07R**		**RWY 25R**		**RWY 25L**	
HEAVY	G	2500	G to	2150	H to	2100	J to	2300
MEDIUM (JET)	M to	1800	C to	1700	A to	1850	H to	1850
MEDIUM (PROP) LIGHT	M to	1800	C to	1700	G to	1150	G	1100

In departures, if possible, cockpit checks should largely be completed prior to line-up and any checks requiring completion on the RWY should be kept to a minimum.

2.1.4.2. Roma
Roma is considerably simpler than Frankfurt, as it handles much less traffic and has one open runway. This traffic can be varied (civil and various military aircraft), meaning that separation minima are comparably large, due to the different approach speeds of the various aircraft.
The approach chosen overflies Urbe airport, used mainly for GA, and an aircraft on the approach would need to be mindful of other aircraft in the TMA flying to/from Fiumicino. A CDTI could be of considerable benefit here.
In the future, well-equipped aircraft will be able to make use of new SIDs and STARs in the TMA, thereby potentially saving fuel, possibly removing the need to hold, and permitting an increase in capacity. Non-equipped aircraft will be restricted to the existing SIDs and STARs.

2.1.4.3. En-route Complexity
The route chosen can be seen (from EUROCONTROL's ASM Upper Airspace chart) to involve the use of a number of separate pre-defined Routes. These Routes pass through the airspace of three different states. There are numerous crossing points with other routes. Therefore, there could be a significant amount of other traffic. The numerous airports in the area will also mean that there is a great deal of climbing and descending traffic.
2005 is likely to see a similar mix of traffic, with some aircraft being equipped with P-RNAV and ADS-B. There will undoubtedly be more traffic in the region.
2015: As the percentage of aircraft equipped with ADS-B increases, and some of the MAS changes to FFAS, then benefits of ADS-B and UPT will be seen, and well-equipped aircraft will have their own airspace.

2.1.5 Type of Control

2.1.5.1. General

The objectives of air traffic services in the “area control service”, as defined by ICAO Annex 11 Chapter 2 §2.2, shall be to:
1) prevent collisions between aircraft;
2) prevent collisions between aircraft and obstructions on that area;
3) expedite and maintain an orderly flow of air traffic.

Tactical control, procedural control, or a combination of tactical and procedural control is used to achieve the above requirements. The type of control impacts the communication capability and performance requirements as well as hazards effects. For example, tactical control depends to a high degree upon reliable air-ground communications. Procedural control is based upon conflict free trajectories, thus reducing the need for availability requirements associated with communication for the purpose of separation assurance. Procedural Procedural control is outside the scope of MA-AFAS.

2.1.5.2. 2007

This timeframe may see the beginning of ADS-B information being available for pilots, allowing limited delegation of spacing for ADS-B/CDTI equipped aircraft. In this timeframe, ADS-B information may also be available for controllers and they may take a more hands-off approach, allowing aircraft to fly UPT to a limited extent. However, ground radar will still be use to control all traffic.

2.1.5.3. 2015

There will be a co-ordinating agency in order to manage the density in FFAS, the entry in this airspace will be restricted to suitably equipped aircraft. Full delegation of separation may be allowed between the entry/exit points to MAS.
The procedure for entering and exiting FFAS from/to MAS could be similar to the procedures used today when changing radio frequency (i.e. changing sector).

2.1.6 Airspace Class

2.1.6.1 Current Classifications

The “en route” environment is defined as “Area Control Service” per ICAO Annex 11 Chapter 2 §2.3.1 a). Also, the ATS services supported by data communications will only be permitted where voice communication remains the primary mean of communication.
Therefore, per Appendix 4 of ICAO Annex 11 Chapter 2, within the Area Control Service, radio communication is required for IFR in Airspace class : A, B, C, D, E, F, G and radio communication is required for VFR in Airspace class : A, B, C, D.
In Germany, IFR flights in Airspace Class G are not permitted.

2.1.6.1.1 Airspace class in Frankfurt

Airspace in the vicinity of Frankfurt Airport		Class C
Co-ordinates in WGS 84	**Limits Upper/Lower**	**Activation Time**
50 04 00 N 08 07 30 E – 50 13 00 N 08 39 00 E – 50 13 00 N 08 53 00 E – 50 04 00 N 09 01 00 E – 49 56 00 N 08 48 00 E – 49 48 00 N 08 33 00 E – 49 51 30 N 08 14 40 E – 50 04 00 N 08 07 30 E	FL 100/ 1500 ft MSL	H 24
50 23 21 N 08 46 43 E – 50 26 00 N 09 00 00 E – 50 12 00 N 09 12 00 E – 50 00 00 N 09 15 00 E – 49 44 50 N 09 13 00 E – 49 43 55 N 08 09 00 E – 50 04 30 N 07 58 30 E – 50 08 00 N 08 00 00 E – 50 16 20 N 08 34 00 E – 50 23 21 N 08 46 43 E excluding the area herein with lower limit 1500 ft MSL	FL 100/ 3500 ft MSL	
49 55 13 N 07 47 36 E – 50 04 30 N 07 58 30 E – 49 43 55 N 08 09 00 E – 49 43 50 N 08 06 30 E – 49 44 40 N 07 53 00 E – 49 55 13 N 07 47 36 E	FL 100/ 4500 ft MSL	
50 14 23 N 08 01 52 E – 50 23 21 N 08 46 43 E – 50 16 20 N 08 34 00 E – 50 08 00 N 08 00 00 E – 50 14 23 N 08 01 52 E	FL 100/ 5000 ft MSL	
50 18 00 N 09 06 52 E – 50 18 10 N 09 23 11 E – 50 01 30 N 09 27 37 E – 50 00 00 N 09 15 00 E – 50 12 00 N 09 12 00 E – 50 18 00 N 09 06 52 E	FL 100/ 5500 ft MSL	
50 10 00 N 07 40 00 E – 50 14 23 N 08 01 52 E – 50 08 00 N 08 00 00 E – 50 04 30 N 07 58 30 E – 49 55 13 N 07 47 36 E – 50 10 00 N 07 40 00 E	FL 100/ FL 65	
50 26 00 N 09 00 00 E – 50 30 00 N 09 20 00 E – 50 18 10 N 09 23 11 E – 50 18 00 N 09 06 52 E – 50 26 00 N 09 00 00 E	FL 100/ FL 65	
50 00 00 N 09 15 00 E – 50 01 30 N 09 27 37 E – 49 45 00 N 09 32 00 E – 49 44 50 N 09 13 00 E – 50 00 00 N 09 15 00 E	FL 100/ FL 65	

<table>
<tr><th colspan="2">Control Zones: Frankfurt Main CTR</th><th>Class D</th></tr>
<tr><th>Co-ordinates in WGS 84</th><th>Ceiling</th><th>Activation Time</th></tr>
<tr><td>ARP: 50 02 00 N 08 34 13 E

50 07 30 N 08 27 00 E – 50 06 15 N 08 38 35 E – 50 07 20 N 08 43 00 E – 50 01 40 N 08 46 00 E – 50 00 55 N 08 42 45 E – 49 55 35 N 08 42 55 E – 49 55 35 N 08 35 55 E – 49 55 00 N 08 35 55 E – 49 54 55 N 08 27 00 E – 49 57 30 N 08 27 00 E – 49 57 50 N 08 21 45 E – 50 00 00 N 08 21 30 E – 50 07 30 N 08 27 00 E</td><td>1500 ft MSL</td><td>1. H 24
excluding the area “Sector Egelsbach” between the co-ordinates
49 59 15 N 08 35 50 E –
50 00 55 N 08 42 45 E –
49 55 35 N 08 42 55 E –
49 55 35 N 08 35 55 E –
49 59 15 N 08 35 50 E
to which the following times of activity apply: daily from SR-30 until SS+30.

2. within Sector Egelsbach the following values apply: flight and ground visibility: 3 km,
ceiling 1000 ft.</td></tr>
</table>

<table>
<tr><th>Airspace with lower limit 1000 FT GND or 1700 FT GND up to 2500 FT GND</th><th>Class E</th></tr>
<tr><th colspan="2">Co-ordinates in WGS 84</th></tr>
<tr><td colspan="2">49 57 20 N 06 12 50 E – 50 14 20 N 06 13 54 E – 50 28 00 N 06 43 35 E –
50 19 56 N 06 56 43 E – 50 26 55 N 07 10 20 E – 50 28 10 N 07 10 20 E –
50 28 10 N 07 36 30 E – 50 17 10 N 07 36 30 E – 50 15 10 N 07 25 10 E –
50 07 10 N 07 35 30 E – 50 07 10 N 07 48 30 E – 50 20 40 N 08 33 10 E –
50 19 42 N 09 10 07 E –
in a clockwise direction on the arc of a circle with a radius of 10 NM centred at
50 09 51 N 09 12 49 E –
49 59 57 N 09 15 00 E – 49 44 28 N 08 52 25 E – 49 23 10 N 08 52 25 E –
49 16 40 N 08 45 45 E – 49 17 21 N 08 11 30 E – 49 10 11 N 07 29 45 E –
along the German-French border –
49 15 32 N 06 40 33 E – 49 20 00 N 06 50 25 E – 49 20 00 N 07 00 45 E –
49 37 00 N 07 22 30 E – 49 42 00 N 07 22 30 E – 49 42 00 N 07 13 00 E –
49 46 00 N 07 13 00 E – 49 46 00 N 06 33 25 E – 49 47 30 N 06 33 25 E –
49 49 58 N 06 30 32 E – 49 54 30 N 06 13 30 E –
along the German-Luxembourg border –
49 57 20 N 06 12 50 E</td></tr>
<tr><th colspan="2">Ceiling</th></tr>
<tr><td colspan="2">1000 ft GND</td></tr>
<tr><th colspan="2">Activation Time</th></tr>
<tr><td colspan="2">H 24 daily with the exception of the areas:
a) “Eifel”</td></tr>
</table>

49 57 20 N 06 12 50 E – 50 14 20 N 06 13 54 E – 50 28 00 N 06 43 35 E –
50 19 56 N 06 56 43 E – 50 26 55 N 07 10 20 E – 50 28 10 N 07 10 20 E –
50 28 10 N 07 36 30 E – 50 17 10 N 07 36 30 E – 50 15 10 N 07 25 10 E –
49 46 00 N 06 43 18 E – 49 46 00 N 06 33 25 E – 49 47 30 N 06 33 25 E –
49 49 58 N 06 30 32 E – 49 54 30 N 06 13 30 E –
along the German-Luxembourg border –
49 57 20 N 06 12 50 E

b) "Rhein"
50 07 10 N 07 41 28 E – 50 07 03 N 07 48 25 E – 50 10 54 N 08 00 51 E –
50 08 00 N 08 00 00 E – 50 04 30 N 07 58 30 E – 49 43 55 N 08 09 00 E –
49 44 28 N 08 52 25 E – 49 23 10 N 08 52 25 E – 49 16 40 N 08 45 45 E –
49 17 21 N 08 11 30 E – 49 34 00 N 08 11 30 E – 49 44 40 N 07 53 00 E –
50 07 10 N 07 41 28 E

Insofar as no IFR flight operations take place at the military aerodRomas Spangdahlem, Büchel, Mendig, Heidelberg, Coleman and Wiesbaden which lie below these airspaces (usually at weekends and on public holidays), the latter can be flown in accordance with the regulations of Airspace G.

2.1.6.1.2 Airspace class in Roma
Roma TMA is Class A.
Roma APP has Classification "D".

2.1.6.2. Future Classifications
By 2005, there may be a move to formalise a new airspace classification scheme, and by 2015 examples of this may be implemented. There will be Unmanaged AirSpace (UMAS), Managed AirSpace (MAS) and FreeFlight AirSpace (FFAS). UMAS is the airspace which is "Outside Controlled Airspace" and it will not be considered by MA-AFAS. MAS will consist of airspace (defined by vertical, lateral and time boundaries) that will be needed to support en-route operations within which the control of aircraft is the responsibility of the ground ATM organisation. FFAS is an area of free routing where the responsibility of separation assurance with surrounding traffic is fully delegated to the aircrew.

2.1.6.2.1 FFAS Limits
In order to validate the autonomous operation application the FFAS limits must be defined. MA-AFAS scope for demonstration of autonomous operation will be limited to showing that the ASAS equipment is capable of assuring the separation between aircraft. Therefore, for this simulated flight, the sectors UP2, EN3, ES3, and their adjacent sectors above FL290 define the FFAS.
Entering the FFAS airspace will be possible by crossing 4D entry and exit point. Exit waypoints will be distributed points corresponding to the intersection of the FFAS boundary and the structured routes in the MAS. For this simulation validation, the entry point will be at NATOR, and the exit point at GRO.

For Entry waypoints, same type of points will be defined but in addition it will be possible to enter the FFAS on points that are not located on a structured route (for example the controller could have given a heading for entering the FFAS).

For entering the FFAS, the pilot will use its CD&R system before entering the FFAS in order to avoid conflicts within the FFAS. In case a conflict in the FFAS is detected before the aircraft is entering the FFAS, only the trajectory inside the FFAS can be modified by the pilot. Any modification of trajectory by the pilot for conflict avoidance inside the FFAS should stay inside the FFAS boundaries but as stated below the pilot can ask for a modification of the entry parameters. The controller has to ensure the separation in the MAS airspace and has to clear the aircraft entry parameters (waypoint or heading) in the FFAS accordingly : the FFAS entry trajectory must be conflict free. Due to safety reason, the pilot can ask for a modification of these entry parameters.

It is also an assumption that the aircraft will fly a direct route from entry point to exit point, but in order to optimise the trajectory (SIGMET, wind) the pilot can deviate from this direct route.
In case the aircraft was flying a heading, the heading will be followed up to the entry point (intersection of the heading with the FFAS boundary), then a direct will be made from the entry waypoint to the exit waypoint as in other cases.
It is assumed that only the exit points need to be negotiated as the aircraft is going back into a route structure. Therefore we suggest that before reaching a certain time and/or distance (TBD) from the FFAS boundary, the pilot will initiate a negotiation proposing an exit 4D point from its trajectory computation. It will be then up to the controller to accept this 4D point or propose a new one.
The negotiation must be finished before another TBD distance/time from the FFAS boundary in order to have time to maneuver in case the control does not accept the exit conditions.

2.1.7 Separation Minima

2.1.7.1. General

Separation by an air traffic unit is obtained by at least one of the following:

1) vertical separation, obtained by assigning different levels selected from:
    a) the tables of cruising levels in ICAO Appendix 3 of Annex 2; or
    b) a modified table of cruising levels, when so prescribed, in accordance with ICAO Appendix 3 of Annex 2 for flight above FL 410.

Correlation of levels to track does not apply whenever otherwise indicated in appropriate aeronautical information publications or air traffic control clearances.

2) horizontal separation, obtained by providing:
    a) longitudinal separation, by maintaining an interval between aircraft operating along the same, converging or reciprocal tracks, expressed in time; or
    b) lateral separation, by maintaining aircraft on different routes or in different geographical areas:

3) composite separation, consisting of a combination of vertical separation and one of the other forms of separation contained in 2) above, using minima for each which may be lower than, but not less than half of, those used for each of the combined elements when applied individually.

Details of current separation minima prescribed by ICAO are contained in the PANSRAC (Doc. 4444) and Part 1 of the Regional Supplementary Procedures (Doc. 7030).
Guidance material relating to vertical separation is contained in the Manual on Implementation of a 300 m (1000 ft) Vertical Separation Minimum between FL 290 and FL 410 Inclusive (Doc. 9574).
Guidance material relating to the implementation of composite lateral/vertical separation is contained in the Air Traffic Services Planning Manual (Doc. 9426).
Spacing between parallel tracks or between parallel ATS route centrelines for which a RNP type is required will be dependent upon the relevant RNP type specified. Guidance material relating to the establishment of ATS routes for use by RNAV-equipped aircraft and to the spacing between routes based on RNP type is contained in ICAO Annex 11 Attachment B.
By 2007 there may be areas using limited delegation of separation, and thus new airborne separation minima guidance will need to be developed. This guidance material may be sufficient by 2015 to allow autonomous aircraft in FFAS.
By 2005 areas of Reduced Vertical Separation Minima (RVSM), which reduces the vertical separation from 2000 feet to 1000 feet, will cover the whole European airspace between specified flight levels. This airspace will only be useable by adequately-equipped aircraft.

2.1.7.2. Separation Minima in Frankfurt

Deviating from the provisions of ICAO Doc. 4444, Part VI, Item 7.4.2 b), the minimum radar separation for approaches to the parallel runway system 07/25 at Frankfurt may be reduced by approach control to 2.5 NM between 10 NM (outer marker) and threshold, provided the following conditions are meet:

1. the preceding aircraft is of the same or a lower weight category. Aircraft of the weight category HEAVY include the B757 as preceding aircraft are excluded from this procedure,
2. the turn-off points of the runway are discernible visually from the control tower,

3. the runway is dry.

The reduced radar separation minimum may also be applied between staggered approaches to the parallel runways. In these cases neither the visual discernibility of the turn-off points (2), nor the runway condition (3) as condition for the application are of importance.
The increased separation minima are:

ATC with Radar		
Preceding Aircraft	**Following Aircraft**	**Radar Separation Minima**
HEAVY	HEAVY	4 NM
HEAVY	MEDIUM	5 NM
HEAVY	LIGHT	6 NM
MEDIUM	LIGHT	5 NM

ATC without Radar		
Preceding Aircraft	**Following Aircraft**	**Separation Minima**
HEAVY	MEDIUM	2 NM
HEAVY	LIGHT	3 NM
MEDIUM	LIGHT	3 NM

The increased separation minima above are not applied:
- to the following aircraft, the pilot of which has announced that he has the preceding aircraft in sight and will maintain an adequate distance himself,
- to the following aircraft the pilot of which renounces the increased separation,
- if the area in which wake turbulence is expected is not penetrated.

Pilots who have the preceding aircraft of the higher weight category in sight and being able to keep a safe distance (for instance, during approach-to-land by remaining above the flight path of the preceding aircraft and landing behind its touchdown point) are requested to inform ATC that an increased distance is not necessary.
The same applies if the pilot wishes to renounce the increased separation under corresponding wind conditions.

2.1.8 Sectorisation

Responsibility for control of individual flights must implement the requirements of ICAO Annex 11 Chapter 3 §3.5.

1. A controlled flight shall be under the control of only one air traffic control unit at any given time.
2. Responsibility for the control of all aircraft operating within a given block of airspace shall be vested in a single air traffic control unit.
3. However, control of an aircraft or groups of aircraft may be delegated to other air traffic control units provided that co-ordination between all air traffic control units concerned is assured. Therefore, transfer of clearance procedures must account for sectorization, which must not impair control of aircraft.

2.1.8.1. Frankfurt Sectorisation

Border of the Frankfurt FIR	
Co-ordinates expressed in WGS 84	**Limits Upper/Lower**
50 20 00 N 06 24 30 E - 50 35 00 N 07 00 00 E - 50 45 20 N 07 59 30 E - 50 48 00 N 08 01 40 E - 51 00 00 N 07 53 00 E - 51 04 00 N 07 58 00 E - 51 05 00 N 08 16 00 E - 51 20 00 N 08 46 00 E - 51 20 00 N 09 56 10 E - 51 21 15 N 10 28 30 E - 50 25 30 N 11 15 00 E - 50 15 30 N 12 06 00 E - German - Czech border - 49 31 54 N 12 36 30 E - 49 31 54 N 11 46 40 E - 49 25 00 N 10 58 00 E - 48 31 40 N 09 33 00 E - 47 48 00 N 09 33 00 E - 47 47 00 N 08 52 00 E - 47 53 00 N 08 51 00 E - 47 34 00 N 07 41 00 E - 47 48 00 N 07 32 00 E - German - French, German - Luxembourg and German - Belgian border - 50 20 00 N 06 24 30 E	FL 245/ GND

Airspace in the vicinity of Frankfurt Airport	
50 10 00 N 07 40 00 E – 50 30 00 N 09 20 00 E – 49 45 00 N 09 32 00 E – 49 43 50 N 08 06 30 E – 49 44 40 N 07 53 00 E – 60 10 00 N 07 40 00 E	
vertical limits	
50 04 00 N 08 07 30 E – 50 13 00 N 08 39 00 E – 50 13 00 N 08 53 00 E – 50 04 00 N 09 01 00 E – 49 56 00 N 08 48 00 E – 49 48 00 N 08 33 00 E – 49 51 30 N 08 14 40 E – 50 04 00 N 08 07 30 E	FL 100/ 1500 ft MSL
50 23 21 N 08 46 43 E – 50 26 00 N 09 00 00 E – 50 12 00 N 09 12 00 E – 50 00 00 N 09 15 00 E – 49 44 50 N 09 13 00 E – 49 43 55 N 08 09 00 E – 50 04 30 N 07 58 30 E – 50 08 00 N 08 00 00 E – 50 16 20 N 08 34 00 E – 50 23 21 N 08 46 43 E excluding the area herein with lower limit 1500 ft MSL	FL 100/ 3500 ft MSL
49 55 13 N 07 47 36 E – 50 04 30 N 07 58 30 E – 49 43 55 N 08 09 00 E – 49 43 50 N 08 06 30 E – 49 44 40 N 07 53 00 E – 49 55 13 N 07 47 36 E	FL 100/ 4500 ft MSL
50 14 23 N 08 01 52 E – 50 23 21 N 08 46 43 E – 50 16 20 N 08 34 00 E – 50 08 00 N 08 00 00 E – 50 14 23 N 08 01 52 E	FL 100/ 5000 ft MSL

50 18 00 N 09 06 52 E – 50 18 10 N 09 23 11 E – 50 01 30 N 09 27 37 E – 50 00 00 N 09 15 00 E – 50 12 00 N 09 12 00 E – 50 18 00 N 09 06 52 E	FL 100/ 5500 ft MSL
50 10 00 N 07 40 00 E – 50 14 23 N 08 01 52 E – 50 08 00 N 08 00 00 E – 50 04 30 N 07 58 30 E – 49 55 13 N 07 47 36 E – 50 10 00 N 07 40 00 E	FL 100/ FL 65
50 26 00 N 09 00 00 E – 50 30 00 N 09 20 00 E – 50 18 10 N 09 23 11 E – 50 18 00 N 09 06 52 E – 50 26 00 N 09 00 00 E	FL 100/ FL 65
50 00 00 N 09 15 00 E – 50 01 30 N 09 27 37 E – 49 45 00 N 09 32 00 E – 49 44 50 N 09 13 00 E – 50 00 00 N 09 15 00 E	FL 100/ FL 65

2.1.8.2. Roma Sectorisation

Border of the Roma APP	
Co-ordinates expressed in WGS 84	**Limits Upper/Lower**
Line joining the following points in counter-clockwise direction: 42 15 12 N 12 20 36 E 42 09 48 N 11 47 39 E then arc of circle of 8 NM radius centred on point 42 02 00 N 11 50 00 E to the point 42 06 28 N 11 41 04 E then 41 55 47 N 11 31 25 E then arc of circle of 5 NM radius centred on point 41 53 00 N 11 37 00 E to the point 41 49 23 N 11 32 22 E then 41 32 13 N 11 56 27 E then arc of circle of 5 NM radius centred on point 41 35 49 N 12 01 05 E then 41 30 58 N 12 02 41 E 41 35 40 N 12 28 30 E 41 30 00 N 12 40 00 E 41 38 30 N 12 46 30 E 41 41 40 N 12 38 00 E 41 45 02 N 12 41 11 E then arc of circle of 5 NM radius centred on point 41 47 55 N 12 35 42 E then to the point 41 48 49 N 12 42 18 E then 41 58 08 N 12 40 00 E then arc of circle of 8 NM radius centred on point 41 56 40 N 12 29 25 E to the point 41 59 57 N 12 39 14 E then 42 10 40 N 12 32 44 E then arc of circle of 8 NM radius centred on point 42 07 23 N 12 22 54 E to the point 42 15 12 N 12 20 36 E	3500 FT AMSL/ GND

2.1.8.3. Other Sectors

LIMM-EU	Milan ACC – East Upper		Frequency :
Vertical Limits	FROM FL 275 TO UNL		
Horizontal Limits	BANKO TARAM GOLAS KALMO LIMBA PIS FRZ ELTAR LUSIL HANNY CANNE CERVI BANKO	454912N/070318E 451630N/084230E 442718N/093700E 441918N/093536E 445536N/092000E 434035N/102328E 440136N/110013E 453848N/103742E 460236N/100700E 461230N/091736E 461004N/085256E 455812N/073242E 454912N/070318E	

LIRR-NES	Roma ACC - North East		Frequency:
Vertical Limits	FROM FL 275/ORG 1 (FL 210 /ORG 2) TO FL 460		
Horizontal Limits	BOL W BOL E MAREL E ELB KAREL PIS GINAR FRZ DENAL KATAR SW NORKY	423701N120307E 423800N115400E 431654N104700E 424300N103300E 432047N101931E 434035N102328E 433754N104900E 440136N110013E 433030N115236E 430306N124042E 425500N130500E	

LIRR-UNR	Roma ACC - Upper North	Frequency:	
Vertical Limits	FROM 1500FT AGSL TO FL460		
Horizontal Limits	OST MEDAL GILIO E ELB E MAREL W BOL E BOL SW NORKY NW ANEDA N PEMAR W LAT TPR	414811N121416E 420312N112236E 422200N105536E 430000N103300E 431700N104700E 423800N115400E 423800N121200E 425500N130500E 422000N133600E 420700N125600E 413200N124200E 413715N122938E	

2.1.8.4. 2007

In the future, as traffic increases, it is likely that in MAS the number of sectors will increase, in order to keep the workload manageable for each controller. This will be tempered by the increasing use of limited delegation of spacing.

2.1.8.5. 2015

Sectors will change to accommodate the FFAS. The FFAS itself may be a type of sector, where the controller monitors aircraft actions, handles density. The controller may also handle entry/exit to MAS until procedures have evolved for this to be done by the the aircraft itself.

2.1.9 Special Use Airspace

Co-ordination between military authorities and air traffic services shall be established per guidelines of ICAO Annex 11 Chapter 2 §2.16. In particular, close co-operation between air traffic services authorities and military authorities should ensure that special arrangements and procedures protect civil aircraft from potentially hazardous military activities

Moreover, activities potentially hazardous to civil aircraft shall be co-ordinated with the appropriate air traffic services authorities per guidelines of ICAO Annex 11 Chapter 2 §2.17. Arrangements shall provide enough time to permit timely promulgation of information regarding the activities in accordance with the provisions of ICAO Annex 15.

In order to achieve both objectives of hazard avoidance and minimal interference with normal flight operations, ICAO Annex 11 Chapter 2 §2.17.2.1 recommends criteria for the design of specific airspace definitions. In particular, ICAO recommends that direct communication between the appropriate ATS authority or air traffic services unit and the organization or units conducting the activities are provided for use in the event that civil aircraft emergencies or other unforeseen circumstances require discontinuation of the activities.

2.1.9.1. Frankfurt-Roma Route

The chosen route passes through the Danger and Restricted areas described in next paragraph.

2.1.9.2. Restricted areas

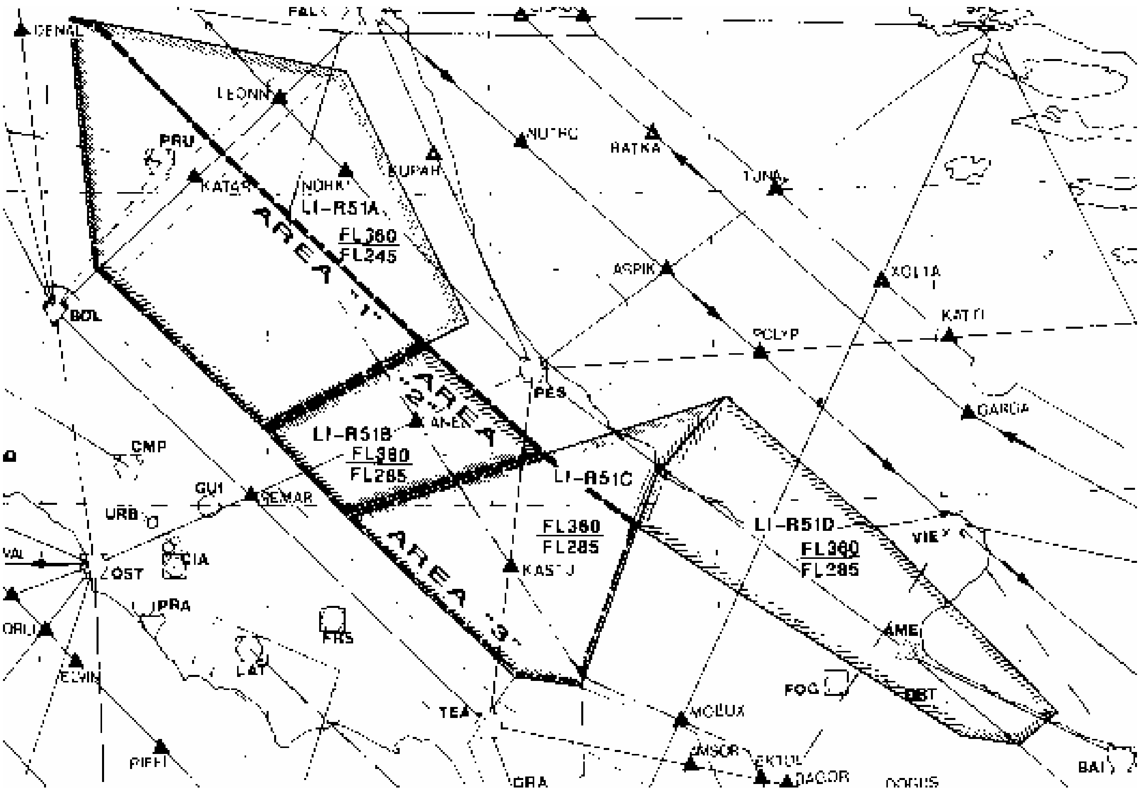
Restricted areas may be penetrated if:

a) the restrictions permit;
b) the DFS has granted permission for penetration generally;
c) the competent ATC unit has granted permission for penetration in individual cases;
d) in the case of military aircraft, the user of the restricted area has granted permission;
e) in the case of rescue flights, prior agreement has been reached between the place of assignment for the rescue flight to be conducted and the respective unit responsible for the activities causing danger in the restricted areas.

Also during the times of activity of a restricted area, IFR flights may be instructed to penetrate restricted areas or be granted clearance by competent ATC unit if there are no activities in the area concerned, within these times. VFR flights will receive clearances for penetration on request within the scope of FIS.

Restricted Areas	Upper limit Lower limit	Remarks
LI R48 (Measured) Area bounded by line joining the following points: 433327N120452E- 432300N132100E 423400N135300E- 421351N125836E 424500N121400E- 433327N120452E	FL245 FL115 North of A15 Fl115 or 5000 FT AGL whichever is lower South of A15	Heavy military air activity
LI R50 Area bounded by line joining the following points: 421943N150335E- 420640N144230E 412456N142331E- 412700N140500E 415814N132102E- 421943N150335E	FL285 FL90	Heavy military air activity

Restricted Areas	Upper limit Lower limit	Remarks
LI R51 **Sector A** Area bounded by line joining the following points: 433327N120452E- 432300N132100E 423400N135300E- 421351N125836E 424500N121400E- 433327N120452E **Sector B** Area bounded by line joining the following points: 421351N125836E- 423015N134206E 420919N141252E- 415814N132102E 421351N125836E **Sector C** Area bounded by line joining the following points: 421943N150335E- 420640N144230E 412456N142331E- 412700N140500E 415814N132102E- 421943N150335E **Sector D** Area bounded by line joining the following points: 421943N150335E- 415320N154440E 411700N162900E- 411100N161800E 411255N160310E- 415639N143754E 420640N144230E- 421943N150335E	FL360 FL245 FL360 FL285 FL360 FL285 FL360 FL285	Heavy military air activity
LIRS DEP/ARR (Level reserved) Military route on A14 between FRZ VOR-R151/25 DME and BOL VOR-R321/20 DME	FL150 FL140	Military route used for/from LIRS



2.1.10 Weather

The climatological data for the period 1961-1990 are shown in the next table.

month	mean temperature (C)		mean presure QFE (hPa)		absolute humidity (gr/m^3)	
	maximun	**minimun**	**15:00**	**06:00**	**15:00**	**06:00**
JAN	3.1	-2.1	1003.4	1003.4	4.7	4.3
FEB	5.2	-1.6	1001.7	1002.0	4.8	4.5
MAR	9.7	0.9	1000.8	1001.5	5.3	5.0
APR	14.2	3.9	999.6	1000.6	6.2	6.1
MAY	19.0	7.9	1000.8	1001.8	7.9	8.1
JUN	22.2	11.3	1002.2	1003.1	9.9	10.1
JUL	24.2	13.0	1002.5	1003.4	10.6	11.0
AUG	23.9	12.7	1002.3	1003.1	10.6	11.0
SEP	20.2	9.7	1003.6	1004.4	9.9	9.4
OCT	14.2	5.8	1003.7	1004.1	8.1	7.4
NOV	7.6	1.7	1002.1	1002.4	6.1	5.7
DEC	4.1	-1.0	1002.3	1002.5	4.9	4.6

The AIRMET and SIGMET information is disseminated as an aeronautical broadcast from 0700 (0600 during legal summer time) until SS+30. The information is broadcast on the FIS frequencies and is repeated every half and full hour for the period of its validity. Between SS+30 and 0700 (0600 during legal summer time), the information is transmitted as an individual broadcast.

ROMA mean daily minimum and maximum temperatures (°C)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Max	12.2	13.1	15.6	18.9	23.3	27.4	30.5	30.6	27.2	22.2	16.9	13.2
Min	3.0	3.6	5.2	7.9	11.4	15.1	17.4	17.5	14.9	10.7	7.6	4.3
	Monthly mean pressure in hectopascal (HPA)											
	1014.6	1013.4	1013.9	1012.9	1014.3	1014.8	1014.4	1014.2	1015.9	1016.6	1015.1	1014.5

2.2 Traffic characteristics

This section describes the traffic characteristics up to the year 2015, which will be used within the MA-AFAS scenario.
Section 2.2.1 describes the traffic demand using Eurocontrol Statistics and Forecast data extrapolated to 2015. Section 2.2.2 gives a short overview of current capacity problems and future increasing throughput programs.
Together with the CFMU data, used in section 2.2.3, an estimated sector traffic density number can be given (section 2.2.4).

2.2.1 Traffic/Schedule Demand

The Eurocontrol Traffic statistics and forecasts document gives forecasts for aircraft movements in Europe. The document provides a prediction of the growth rate of the number of IFR flights in 13 European States (including Benelux, France, Germany, Switzerland, Italy, UK, Spain).
National, regional and global statistics from 1974 to 1997 were produced and released, together with short and long-term forecast data (i.e. up to 2004 and 2015) using baseline, high and low scenarios.
Between 1997 and 2015 the growth rate of number of IFR flights is expected to be about:

- 61% for the low scenario (2.7% per annum),
- 91% for the baseline scenario (3.7% p.a.) and
- 129% for the high scenario (4.7% p.a.).

The average annual growth rates by period are:

1990-1995	Historical: 4.0% p.a.	
1995-2000	Low:	4.1% p.a.
	Base:	4.9% p.a.
	High:	5.9% p.a.
2000-2010	Low:	2.7% p.a.
	Base:	3.8% p.a.
	High:	4.9% p.a.
2010-2015	Low:	2.5% p.a.
	Base:	3.0% p.a.
	High:	3.5% p.a.

More than 7,500,000 flights were recorded in the EUROCONTROL area in 1998 representing around 95% of the flights in the ECAC area. As the ECAC area expanded between 1997 and 1998, the exact percentage increase that this overall figure represents cannot be calculated. Using comparable geographical sources, however, it can be assumed that the traffic increased by 5.7%, slightly above the baseline forecast prepared in 1997.
The annual growth percentage is assumed to be 3.7% and this will be used within MA-AFAS.
The following three tables show "Traffic statistics and forecasts" data extrapolated up to 2015. The annual growth percentage is assumed to be 3.7%.

2.2.1.1 ITALY Traffic Forecasts

ITALY	**1999**	**2000**	**2005**	**2007**	**2015**
DOMESTICS	398,325	426,250	521,600	562,000	751,565
DEP/ARRIVALS	590,551	640,735	871,435	943,765	1,262,100
LONG HAUL (WESTERN)	16,449	17,950	24,700	26,750	35,773
LONG HAUL (SOUTHERN)	10,385	11,350	14,450	15,150	20,260
LONG HAUL (EASTERN)	10,492	11,450	13,850	14,350	19,190
SHORT HAUL (WESTERN EUROPE)	290,734	314,750	393,080	420,140	561,855
SHORT HAUL (MEDITERRANEAN)	56,455	62,010	89,210	98,010	131,069
SHORT HAUL (NORTH AND EAST EUROPE)	206,036	223,225	336,145	369,365	493,953
OVERFLIGHTS	388,071	424,950	566,460	614,340	821,560
OVERFLIGHTS NORTH ATLANTICS	6,962	7,685	10,435	11,485	15,360
OVERFLIGHTS REST AMERICA	98	125	125	135	180
OTHER OVERFLIGHTS	381,011	417,140	555,900	602,720	806,020
TOTAL NUMBER OF FLIGHTS	**1,376,947**	**1,491,935**	**1,959,495**	**2,120,105**	**2,835,225**

2.2.1.2 SWITZERLAND Traffic Forecasts

SWITZERLAND	1999	2000	2005	2007	2015
DOMESTICS	28,878	30,650	33,600	33,600	44,933
DEP/ARRIVALS	422,865	462,985	575,505	608,585	813,863
LONG HAUL (WESTERN)	11,550	12,850	14,300	14,650	19,591
LONG HAUL (SOUTHERN)	4,729	5,300	5,800	6,350	8,492
LONG HAUL (EASTERN)	9,987	11,100	12,250	12,950	17,318
SHORT HAUL (WESTERN EUROPE)	187,582	203,900	257,880	277,140	370,620
SHORT HAUL (MEDITERRANEAN)	59,413	66,175	83,815	88,575	118,452
SHORT HAUL (NORTH AND EAST EUROPE)	149,604	163,660	201,460	208,920	279,390
OVERFLIGHTS	522,742	563,280	735,280	790,700	1.057,406
OVERFLIGHTS NORTH ATLANTICS	10,454	11,450	15,670	17,000	22,734
OVERFLIGHTS REST AMERICA	2,815	3,100	3,600	3,690	4,935
OTHER OVERFLIGHTS	509,473	548,730	716,010	770,010	1,029,737
TOTAL NUMBER OF FLIGHTS	**974,485**	**1,056,915**	**1,344,385**	**1,432,885**	**1,916,202**

2.2.1.3 GERMANY Traffic Forecasts

GERMANY	1999	2000	2005	2007	2015
DOMESTICS	446,236	461,930	592,230	621,230	830,773
DEP/ARRIVALS	1,239,919	1,327,805	1,841,975	1,985,275	2,654,916
LONG HAUL (WESTERN)	46,596	48,000	54,450	55,700	74,488
LONG HAUL (SOUTHERN)	16,174	16,800	17,500	17,500	23,403
LONG HAUL (EASTERN)	30,555	31,000	31,400	31,450	42,058
SHORT HAUL (WESTERN EUROPE)	552,176	596,610	845,430	925,150	1,237,207
SHORT HAUL (MEDITERRANEAN)	240,966	257,755	404,895	445,845	596,230
SHORT HAUL (NORTH AND EAST EUROPE)	353,452	377,640	488,300	630	681,530
OVERFLIGHTS	792,870	861,465	1,033,575	1,094,125	1,463,177
OVERFLIGHTS NORTH ATLANTICS	15,713	17,500	22,470	24,200	32,363
OVERFLIGHTS REST AMERICA	765	860	1,000	1,060	1,418
OTHER OVERFLIGHTS	776,392	843,105	1,010,105	1,068,865	1,429,397
TOTAL NUMBER OF FLIGHTS	**2,479,025**	**2,651,200**	**3,467,780**	**3,700,630**	**4,948,866**

2.2.2 Throughput

Throughput is defined within this chapter as the maximum amount of traffic through a sector, airspace and location. Throughput is expected to improve based on the use of the tools in MA-AFAS.

There are different methods to increase the throughput, some examples are:

Strategic planning of Airspace:

Route network development	Developing a more efficient route network.
National re-sectorisation	Redefining the sectors, in combination for example with the route network development.

Better use and management of airspace:

Flexible use of airspace	Increasing the available airspace, for example by using military airspace for civil aviation during the peak hours.
Reduced Vertical Separation Minima (RVSM)	RVSM will increase the En-route capacity by giving 6 additional Flight levels in the most preferred level-band.
Area Navigation (RNAV)	Fixed waypoints are no longer constraints for the flight path.
Routing Flexibility using RNAV	For example, flexible “fixed” arrival routes are possible due to RNAV.
Free Route Airspace Concept	Efficient use of airspace. Controller responsibility.
Free Flight Airspace	Efficient use of airspace. Pilot responsibility.

Controller workload:

ATC procedures	
Level Flight Spacing	Lining up aircraft Pilot responsibility.
Lateral crossing and passing	Crossing and passing of aircraft. Pilot responsibility.
In-descent spacing	Longitudinal spacing between aircraft. Pilot responsibility.
System support	For example HMI and/or tools to improve the controller situational awareness. Tools which give advisories to the controller.

This is expected to lead to:

- Increased capacity
- Reduced delays
- Improved flight profiles

Further analysis will show to what extent capacity increases and delay reductions will be expected, for various sectors and airspace types, and by location.

In 1999 74% of the ATFM delays were caused by ATC capacity (En-route) and 7% by ATC capacity (Airport).

74% capacity (En-route)
7% ATC capacity (Airport
5% Weather (Airport)
4% Military exercises (En-route)
2% Technical Reason
2% Staff Shortage
6% Others

RVSM will increase the En-route capacity by giving 6 additional Flight levels in the most preferred level-band.
All these Airspace and Navigation initiatives are expected to increase the En-route capacity around 2006-2008 by approximately 70%, which is more than the expected traffic growth in that same period. That means that as of 2006-2008, the main cause of air traffic delays in Europe is expected to be the airports.

2.2.3 Track Occupancy

The Eurocontrol Central Flow Management Unit (CFMU) produces daily traffic data, which record flight plan information for aircraft in the ECAC area. The flight plan information can be used to estimate the instantaneous positions of aircraft, which allows a peak density to be calculated.
When analysing the CFMU data, the following factors must be taken into account:

- Data for all IFR aircraft should be included in the samples. Some IFR traffic, which did not file flight plans, will not be shown in the traffic. It is expected that in the core area of Europe, the amount of this traffic is very small (less then one percent).
- Some airlines file multiple flight plans, which artificially increases the number of aircraft in the sample. While most of these duplicates have been removed, it is expected that a few remain, resulting in an increase of a few percent in the sample.
- Data for all VFR traffic is not included. It is expected that this would result in an increase of a few percent in the sample.

The data samples in this section are taken from 8 September 2000, which is a Friday and therefore a busy day as well.
The ASM Chart (Airspace Management Planning Chart) illustrates the FUA (Flexible Use of Airspace) concept and will be used together with the Statfor and CFMU data to calculate current and future track occupancy data.

CFMU flight plan example

From LIRF to EDDF

AZA404

2000 09 08 1445 hr

1505:LIRF:LIRFELB5A:	0
1516:MEDAL:LIRFELB5A:	171
1520:GILIO:LIRFELB5A:	241
1525:ELB:UM729:	307
1530:NORNI:UM729:	348
1533:BELEL:UM729:	350
1535:SPEZI:UM729:	350
1537:IDONA:UM729:	350
1539:LUKIM:UN851:	350
1543:MONEB:UN851:	350
1551:DESIP:UN851:	350
1554:PEPAG:UN851:	350
1555:ABESI:UN851:	350
1604:ELMUR:UN851:	350
1607:KUDES:T163:	350
1612:LADOL:T163:	319
1616:NELLI:T163:	240
1620:LOPNI:T163:	240
1627:PSA:EDDFPSA1W:	100
1628:*0FFM:EDDFPSA1W:	100

1631:CHA:EDDFPSA1W: 050
1638:EDDF:EDDFPSA1W: 0 ;

Sector crossed with entry and exit times:
1505:LIRRDEP: 1516
1516:LIRRNW1: 1523
1517:LISRS10NOTE: 1553
1523:LIRRNW2: 1533
1524:LIAIPNOTE: 1553
1533:LIRRMIW: 1547
1547:LIRRMIE: 1555
1555:LSAZUP3: 1610
1608:EDFFUIR: 1616
1610:EDUUTG1: 1612
1612:EDUUT2U: 1616
1616:EDFBDP2: 1622
1622:EDFFOR1: 1626
1626:EDFFOR3: 1628
1628:EDDFTMA: 1638

2.2.4 Sector Traffic Density

For a flight from Rome (LIRF) to Frankfurt (EDDF), the following sectors are crossed (using a CFMU data file from 2000 09 08 the amount of traffic for one day is mentioned as well):
All the data in the CFMU file were scanned on the appearance of a specific sector name. This resulted in the following traffic density data per sector:

Sector	Traffic density
LIRRDEP	(553)
LIRRNW1	(524)
LIRRNW2	(484)
LIRRMIW / LIRRMUW	(451 / 193)
LIRRMIE / LIRRMUE	(429 / 109)
LSAZUP3 / LSAZUP	(576 / 1406)
EDFFUIR	(3663)
EDUUTG1	(656)
EDUUT2U	(443)
EDFBDP2	(494)
EDFFOR1	(525)
EDFFOR3	(409)
EDDFTMA	(1628)

Where the traffic density is defined as the amount of traffic passing through this sector on September the 8th according to the CFMU.

With the use of a CEU Chart, shows the sectors as used by CFMU, more detailed information can be given about the sector density. The structure of the CFMU sectors will be used, together with peak information of the traffic, to get a better traffic distribution through the sector.
The Statfor annual growth percentage is assumed to be 3.7% and will be used to calculate the sector traffic density in the future (2005-2015).

2.2.5 Aircraft Mix

This section provides the distribution of aircraft among three categories for the years 2005, 2008 and 2015. These three categories are related to the wake vortex types: Heavy, Medium and Light. These types are described in the Section 2.1.4 of this document.
The aircraft mix is highly dependant on the area which is considered. As no precise figures related to the selected areas are available, a generic aircraft mix is proposed. This distribution is derived from a combination of the Airbus and Boeing aircraft forecasts.

	2005	**2008**	**2015**
Heavy	23%	24%	25%
Medium	71%	69%	66%
Light	6%	7%	9%

Table 1: Aircraft mix

2.2.6 CNS Equipment

This section describes briefly part of the future CNS equipment which will be required to cope with the MA-AFAS applications. When available some figures related to the percentage of aircraft equipped with such equipment is provided.
The equipment is described for each type of airspace: Ground, Approach/MAS, En-route/MAS and En-route/FFAS, and for each group of MA-AFAS applications: Taxi Management and ground CDTI applications, 4D applications, Precision Approach application, CDTI/ASAS applications. No information is provided for the Unmanaged Airspace (UMAS) as it is outside the scope of MA-AFAS as mentioned in Section 2.1.6.2. To end, a nominal set of options of avionics packages is proposed.

2.2.6.1. Communication

The communication equipment is divided into:

- Voice Communication equipment
- Data communication equipment.

2.2.6.1.1 Voice communication equipment

The voice communications are handled by the Audio Management Unit (AMU) and are conveyed via two VHF transceivers.
Within the MA-AFAS time frame, aircraft have to be 25 kHz and 8.33 kHz compliant using either current analogue VHF technologies or new digital technologies based on the VDL network.
The VDL Mode 3 technologies which provides digital voice capabilities should be available around 2010 but will not be used within the scope of MA-AFAS.
Regarding the MA-AFAS applications no specific requirements concerning voice communication equipment are mentioned: the voice communications will be ensured with current VHF technologies.

2.2.6.1.2 Data communication equipment

Data communication services are divided into:

- Air/Ground communication services
- Air/Air communication services.

2.2.6.1.2.1 Air/Ground communication equipment

The Air/Ground communications constitute the core of the CNS/ATM Package 1, which is the first step of implementation of the CNS/ATM concept defined by OACI.

Within the time frame of MA-AFAS, it is supposed that aircraft will be progressively equipped to perform these CNS/ATM Package 1 services which are:

- CPDLC, CM, and FIS services which provide the services CIC, ACM, DSC, CAP, D-OTIS as defined by ODIAC
- ADS service (ADS-C to support FLIPCY and CAP services and ADS-B)
- AOC services.

To perform these services, aircraft have to be equipped with a Communication Management Unit (CMU). The CMU hosts the ATC, ADS and AOC communication services and provides management and access to the data link networks which may be ACARS or ATN compatible data link networks.
Within the scope of MA-AFAS, only ATN is considered and only VDL Mode 2 and VDL Mode 4 are used.
Note: The CMU should be compatible with ATN over SATCOM, Mode S and HF sub-networks but it is outside the scope of MA-AFAS.
To access the VDL network aircraft have to be equipped with:

- VHF antennas
- A VHF Data Radio (VDR).

In addition, to handle the communication messages aircraft have to be equipped with a Multipurpose Control and Display Unit (MCDU).
The Programme Link2000+, the European programme of implementation of the CNS/ATM Package 1, provides some figures concerning the percentage of aircraft equipped to perform the CNS/ATM Package 1 services: ACM, CIC, DCL, CAP, FLIPCY and D-OTIS. These figures are provided in the following table for the years 2008 and 2015.
No distinction is made between the different types of airspace and between the different services as it is assumed that aircraft will be equipped to perform all the services at the same time.

	2008	**2015**
CNS/ATM package 1 equipped aircraft	45%	85%

Table 2: Communication equipment rate

2.2.6.1.2.2 Air/Air communication equipment

Within MA-AFAS scope, air/air communications are ensured by ADS-B based on VDL Mode 4.
The dedicated airborne equipment is described in the previous section 2.2.6.1.2.1

2.2.6.1.2.3 MA-AFAS applications

The following table summarises the specific communication services required by the MA-AFAS applications and which have to be handled by the airborne equipment described previously.
For CDTI/ASAS applications no air/ground communication services are mandatory although CPDLC with additional services could be helpful. Such services are called CPDLC++ and refer to the CPDLC services enhanced to provide clearances for delegated manoeuvres.

	MA-AFAS applications	Communication services
Ground	Taxi management application	- CPDLC
MAS/Approach	4D applications	- COTRAC
	CDTI/ASAS applications	- ADS-B - CDPLC++ (optional)
MAS/En-route	CDTI/ASAS applications	- ADS-B - CDPLC++ (optional)
	4D applications	- COTRAC
FFAS	CDTI/ASAS applications	- ADS-B - CDPLC++ (optional)
	4D applications	- COTRAC

Table 3: MA-AFAS communication services

2.2.6.2. Navigation

The aircraft shall be capable to meet any navigation requirements of each airspace in which they fly. Therefore the airborne equipment will have to ensure the new en-route and TMA mandatory navigation modes (e.g. RNAV being mandatory in more and more airspace) with the various navigation requirements associated (e.g. RNP5, 1).

In addition to these new navigation requirements, the deployment of new systems (e.g. GNSS with augmentation systems) along with the progressive withdrawal of conventional navaids (e.g. NDB, VOR) will also have an impact on the airborne navigation equipment.

Within the MA-AFAS time frame:

- the RNAV will become mandatory in all en-route and TMA airspace in 2010 (RNP1 for en-route, RNP to be defined for TMA). Consequently, aircraft will have to be compliant with such requirements and to do so may rely on the following equipment:
  - Conventional avionics e.g. multi-DME
  - Augmented GNSS (e.g. SBAS, GBAS or GRAS receiver).
  - GNSS coupled with INS/IRS.
- for the landing phases, due to the co-existence of multiple equipment, aircraft will have to be equipped with one or several of this equipment:
  - ILS receiver
  - MLS receiver
  - SBAS receiver
  - GBAS receiver.

Within the MA-AFAS scope:

- the en-route and TMA navigation is mainly based on SBAS, GBAS and GRAS; aircraft will have to be equipped with the corresponding SBAS/GBAS/GRAS transceiver.
- the Precision Approach is based explicitly on GBAS.

To comply with these new navigation requirements the FMS will be enhanced to perform navigation computations and to ensure the required navigation precision.

As RNAV/RNP1 will be mandatory in 2010 (refer to EUROCONTROL Navigation Strategy), it can be assumed that 80% of aircraft will be RNAV/RNP1 compliant equipped in 2008 and 100% in 2015.

Regarding the MA-AFAS applications, the following table summarises the specific navigation equipment required for each group of MA-AFAS applications and for each type of airspace. As no explicit requirements have been expressed for Taxi management and CDTI/ASAS applications, GBAS/SBAS/GRAS is not associated to these applications.

The Advanced FMS mentioned in the table is responsible for handling either the CDTI/ASAS applications (i.e. In-Trail Climb/Descent, Lateral Crossing and Passing, In-Descent Spacing (IDS) and Level Flight Spacing (LFS) and the Autonomous Aircraft applications) or the Taxi Management application or the 4D application.

	MA-AFAS applications	Navigation equipment
Ground	Taxi Management	- Advanced FMS
	Ground CDTI application	- Advanced FMS
MAS/Approach	Precision Approach	- GBAS
	4D applications	- GBAS/SBAS/GRAS - Advanced FMS
	CDTI/ASAS applications	- Advanced FMS
MAS/En-route	CDTI/ASAS applications	- Advanced FMS
	4D applications	- SBAS/GBAS/GRAS - Advanced FMS
FFAS	CDTI/ASAS applications	- Advanced FMS
	4D applications	- SBAS/GBAS/GRAS - Advanced FMS

Table 4: Navigation equipment

2.2.6.3. Surveillance

2.2.6.3.1 Ground surveillance

Within the MA-AFAS scope, aircraft have to be equipped for radar surveillance. The basic equipment is composed of a Mode A/C transponder for SSR surveillance (PSR which is required in TMAs does not require any particular airborne equipment).

If Mode S ground infrastructure is available within the MA-AFAS scope, aircraft may be required to be equipped with a Mode S equipment. In that case, the current airborne transponder must be replaced by a Mode S transponder of level 1, at least, which is compatible with the standard Mode A/C operation.

From 2005 and beyond, the ADS service (ADS-Contract and ADS-Broadcast) may be used to improve the SSR or Mode S surveillance. It will depend on the ground infrastructure defined in the MA-AFAS scope.

The airborne equipment which provides the ADS services (ADS-B and ADS-C) is described in Section 2.2.6.1.

2.2.6.3.2 Air surveillance

Some MA-AFAS applications are based on an air/air surveillance which is provided by ADS-B or TIS-B services.

In the MA-AFAS scope, ADS-B is provided by VDL Mode 4. The associated airborne equipment is described in Section 2.2.6.1.

Note: Mode-S or UAT provide also ADS-B services but these means are not considered within MA-AFAS.

The information provided by ADS-B or TIS-B is displayed as the CDTI on the Navigation Display (ND). This CDTI increases the traffic situational awareness of the aircrew.

2.2.6.3.3 MA-AFAS applications

The following table summarises the specific surveillance equipment required by each MA-AFAS application for each type of airspace.

	MA-AFAS applications	Surveillance equipment
Ground	Ground CDTI application	- ADS-B or TIS-B - Advanced FMS - ND (CDTI capability)
MAS/Approach	CDTI/ASAS applications	- ADS-B or TIS-B - Advanced FMS - ND (CDTI capability)
MAS/En-route	CDTI/ASAS applications	- ADS-B or TIS-B - Advanced FMS - ND (CDTI capability)
FFAS	CDTI/ASAS applications	- ADS-B only - Advanced FMS - ND (CDTI capability)

Table 5: Surveillance equipment

2.2.6.4. Avionics Packages

From the various equipment identified in the previous sections a possible set of options of avionics packages is proposed in Table 6 for the different type of airspace considered.

PtoP stands for Point to Point communications and represents the equipment which provides the communications services between ATC or AOC and aircraft, i.e. CPDLC, CM and FIS services, ADS and COTRAC services, and AOC services. The CPDLC++ services are distinguished as they are optional. For each type of airspace, the applications which have to be handled by the Advanced FMS are specified between parenthesis.

	Equipment
Ground	PtoP + ADS-B/TIS-B + ND (CDTI capability) + Advanced FMS (for Ground CDTI and Taxi Management)
Approach/MAS	PtoP + CPDLC++ + GBAS + ADS-B/TIS-B + ND (CDTI capability) + Advanced FMS (for Precision Approach and Spacing)
	PtoP + GBAS + ADS-B/TIS-B + ND (CDTI capability) + Advanced FMS (for Precision Approach and Spacing)
	PtoP + CPDLC++ + SBAS/GBAS/GRAS + ADS-B/TIS-B + ND (CDTI capability) + Advanced FMS (for 4D, Precision Approach and Spacing)
	PtoP + SBAS/GBAS/GRAS + ADS-B/TIS-B + ND (CDTI capability) + Advanced FMS (for 4D, Precision Approach and Spacing)
	GBAS (Precision Approach only)
	ADS-B/TIS-B + ND (CDTI capability) + Advanced FMS (Spacing only)
En-route/MAS	PtoP + CPDLC++ + SBAS/GBAS/GRAS + ADS-B/TIS-B + ND (CDTI capability) + Advanced FMS (for 4D and CDTI/ASAS)
	PtoP + SBAS/GBAS/GRAS + ADS-B/TIS-B + ND (CDTI capability) + Advanced FMS (for 4D and CDTI/ASAS)
	PtoP + CPDLC++ + ADS-B/TIS-B + ND (CDTI capability) + Advanced FMS (for CDTI/ASAS)
	PtoP + ADS-B/TIS-B + ND (CDTI capability) + Advanced FMS (for CDTI/ASAS)
En-route/FFAS	PtoP + CPDLC++ + SBAS/GBAS/GRAS + ADS-B + ND (CDTI capability) + Advanced FMS (for 4D and Autonomous Aircraft)
	PtoP + SBAS/GBAS/GRAS + ADS-B + ND (CDTI capability) + Advanced FMS (for 4D and Autonomous Aircraft)

Table 6: Avionics packages per type of airspace

2.2.7 Aircraft Performance

2.2.7.1. Speed

This section describes the speed mix which refers to the optimal and operating speed characteristics of the aircraft.

Two tables are proposed which highlight 1) the speed policy applied by the controller at different phases of flight (Table 7) and 2) the cruising speeds required by airlines to optimise the flight profiles (Table 8. In this table data are issued from a CFMU traffic sample). These two tables are global and do not distinguish the different categories of aircraft.

Phases of flight	Speed range (expressed in CAS unless mentioned)
Cruise	0.65/0.68 - 0.82/0.84 Mach
Initial descent	280/300 Kts max
IAF	240/250 Kts max
Initial Approach segment before the FAF	There may be some points with specific speed constraints at 200/220 Kts
FAF	150/170 Kts max
Landing	60/70 Kts – 130/140 Kts

Table 7: Speed distribution

Speed range (expressed in TAS)	Distribution
< 200 Kts	6%
200Kts ≤ Speed < 300 Kts	24%
300Kts ≤ Speed < 400 Kts	10%
400Kts ≤ Speed < 500 Kts	59%
≥ 600 Kts	1%

Table 8: Required Cruising speeds

2.2.7.2. Altitude

To provided an overview of the aircraft performance in term of flight profile, the distribution of RFL required by the airlines is proposed.

The RFL distribution is highly dependent on the airspace considered. As no figures are available, the RFL distribution which is proposed is issued from a CFMU traffic sample containing all the flight plans for the 24th of March 2000.

To extrapolate these figures for the year 2008 and 2015, the following hypothesis are proposed:

- The number of turbo-prop will decrease during the next years. As these aircraft mainly evolve between FL110 and FL250, the percentage of aircraft at these levels should decrease.
- RVSM will bring additional flight levels above FL290. The proportion of aircraft above FL290 should increase slightly.
- Aircraft will require higher RFL as performances of aircraft increase.

Altitude bands	2000	2008	2015
FL0-30	1%	1%	1%
FL40-100	7%	7%	7%
FL110-250	35%	30%	25%
FL260-290	17%	19%	22%
FL300-350	33%	36%	38%
FL360+	7%	7%	7%

Table 9: RFL distribution

2.2.7.3. Climb/Descent

This section describes the proportion of evolving traffic in each type of airspace.

The climbing/descending aircraft distribution is highly dependant on the area considered and no precise figures are available.

2.3 Technical Characteristics

2.3.1 Introduction

The purpose of this chapter is to describe the characteristics of the ground CNS/ATM system architecture as required in support of the MA-AFAS Operational Concept (OC). This concept covers a mix of different Aircraft capabilities, with a consequence that the ground CNS/ATM system will have to provide simultaneous support for all aircraft (A/C) capability groups. The "basic" CNS/ATM infrastructure- as described here- represents a minimum environment required for the less equipped A/C and is mainly based on the information provided in the EATMS/ State-of-the-Technology in CNS document. Additionally, specific aspects relevant to MA-AFAS will be estimated and highlighted for two target years, 2005 and 2015.

Wherever applicable, the allocation of the infrastructure to the Airport, Terminal (TMA) and En-route environments will be indicated as well.

Only a brief description of the ground ATM system may be provided within this document. Only the systems involved in the tactical flight phase (focus of the MA-AFAS project) have been indicated.
It is important to emphasise that the data link cannot cover all ATM communication needs, so it cannot completely replace traditional voice communications. Voice remains the most appropriate means for time-critical ATM communication tasks, additionally, voice capability is required as a backup for the data link. It can be concluded that voice and data communications will co-exist even beyond the MA-AFAS time frame.

2.3.2 Communications (COM)

2.3.2.1. A/G Voice Communications

- **Basic**

Currently, voice Air/Ground (A/G) communications represent the only means for the controller to access the pilot and assume the effective control over an A/C. While the most of MA-AFAS advanced functions will rely upon the Air/Air (A/A) and A/G data links, voice communications will still have to be supported within the whole MA-AFAS airspace as a backup for such data links. This mandates the onboard carriage of doubled VHF transceivers and (optionally for long-haul A/C) one HF transceiver.
Different Air Traffic Service Units (ATSUs) in Europe currently use different VHF voice communications systems. There are significant local differences with respect to the scope of the radio functions supported by the Voice Communications System (VCS), methods of providing the required coverage (climax, best transmitter selection e.t.c.) and the interconnecting ground infrastructure (leased analogue lines, digital lines, meshed radio networks). Nevertheless, until recently the ground VHF radio station in all cases produced the same analogue DSB-AM radio signal which could have been received by any A/C.
This situation changed with the recent introduction of the 8.33 kHz channel grid in the European upper space. As the new 8.33 kHz equipment is not interoperable with old 25 kHz-based equipment, dedicated 8.33 kHz airspace above FL 245 is- with local exceptions- available only to the 8.33 kHz- equipped A/C.
The introduction of the new 8.33 kHz system was guided by the requirement that the ground VCS systems and controller's procedures should not change. It will therefore be assumed that MA-AFAS A/C is both 25 kHz- and 8.33 kHz- capable and that expected transitions between both VHF systems during the flight may be regarded as transparent to the MA-AFAS OC. Similarly, the HF ground support for both AOC- and ATS communications is assumed to be further available for the MA-AFAS A/C.

- **MA-AFAS**

2005

No MA-AFAS specific modifications of onboard and ground components of the existing VHF or HF voice system are required in the 2005 time frame. MA-AFAS themes (in particular 4D Enroute, Taxi Management) generally assume the availability of the A/G voice communications for tactical purposes and as a backup for the A/G data link by 2005 and beyond.

2015

The MA-AFAS OC requires that existing analogue A/G voice communications remain available also in the 2015 time frame.

NOTE: Digital voice (VDL3) will not be supported in MA-AFAS trials.

2.3.2.2. G/G Voice Communications

- **Basic**

Currently time-critical Ground/Ground (G/G) phone/intercom voice communications are used to exchange the co-ordination information between the Air Traffic Service Providers (ATSPs) units and other ATM entities (e.g. military units). This kind of communications is accompanied with high requirements with respect to the system availability, call-set-up times e.t.a. and relies upon ATSP's private analogue and digital transport networks.

- **MA-AFAS**

No MA-AFAS specific requirements upon the ATSP's phone network infrastructure and procedures exist. However, the MA-AFAS OC reqires the availability of the G/G voice communications at least as a backup for ground data networks- within 4D-En-route (AOC- ATS CDM) theme.

2005

It may be expected that by 2005 the same G/G voice communications systems will be used as today.

2015

The procedures will remain unchanged, but the analogue G/G communication infrastructure will be largely replaced by modern digital telecommunications networks. The amount of the time-critical G/G voice communications will decrease due to the growing usage of the G/G data link (On-Line Data Interchange-OLDI, Inter-Centre Communications-ICC).

2.3.2.3... Data Communications- Networks

- **Basic**

The G/G information exchanges are required during the whole life cycle of a particular flight, including the TORCH elements related to the strategic and pre-tactical planning. It may be assumed that current communications systems and procedures for the exchanges of strategic data and information will remain to be available by both year 2005 and 2015. The improvements in this field are both welcome and expected, but will not significantly influence the MA-AFAS OC. As the OC focuses to the tactical execution of the flight, starting with the approved Daily Operational Plan (DOP), only the G/G communications which are essential for the flight execution need to be described here.

- **MA-AFAS**

The MA-AFAS OC reqires the availability of the G/G data communications within 4D-En-route theme (Collaborative Decision Making/ CDM between AOC and ATS).
Although not explicitely required by the OC, it may be assumed that existing ATS procedures (e.g. OLDI/ SYSCO) and supporting communication infrastructure for the time-critical coordination between ATS units will both be available and used by 2005 and beyond.
G/G data communications are also required in support of the A/G data link between the AOC- or ATS End Systems (hosting the data link applications and services) and the ground radio resources. These generally comprise VDL2 Remote Ground Stations- RGS, VDL 4 Ground Stations - GS, ACARS RGS and SATCOM Ground Earth Stations-GES, however only VDL2 RGS and VDL4 GS will be required for MA-AFAS trials.
The overall ground network topology- as required in support of A/G data link communications- is outlined in the Figure 2. It indicates several options which are expected to co-exist by the year 2005 and later.

NOTE: All options will be briefly described, however the ACARS data link and SATCOM are outside the scope of MA-AFAS trials.

2005

It may be expected that national CAAs will continue to use existing AFTN- based communications infrastructure and corresponding services. On a local basis, the quality of service may be increased by using e.g CIDIN in addition to AFTN. Without respect to the underlying communication technology, it may be assumed that at selected ATS units AFTN-capable nodes will be available for the exchange of the flight plan- and other data which use the MHS (Message Handling Services). National AFTN/ CIDIN networks will be interconnected by using AFTN/ATN- or CIDIN/ATN gateways, respectively. Similarly, the Airlines will continue to use AFTN-based End Systems to submit the flight plan data to the ATSPs and for other non time-critical AOC communications.
While the ATN CNS/ATM package 1 includes support for the time-critical inter-facility data communications (ICC), it is not expected that this kind of communications will be used in Europe by 2005, as the equivalent non- ATN OLDI standard is already widely in use. OLDI (an implementation of SYSCO-concept) is a message transfer protocol for the exchange of co-ordination- and other time-critical messages between ATSP systems. It is also widely used for the co-ordination purposes between ATSP systems and external military units. It supplements existing telephone voice communications (which also remain to be available in the future for the co-ordination purpose).

OLDI makes use of dedicated leased lines or X.25 networks and is not ATN-compatible (does not make use of an ATN internet). While initially deployed for international co-ordination purposes, it will by 2005 also cover a part of the CAA- internal co-ordination activities.
The existing RADNET (RADar data exchange NETwork) and other similar regional networks will continue to be used for the distribution of the PSR/ SSR radar data. These networks currently use different underlying communications technologies (mainly dedicated leased lines or X.25). While it may be expected that new technologies may be adopted, the end-to-end functionality and the format of the radar data (ASTERIX) will remain essentially the same as today.
As a supplement to RADNET, the TCP/IP based NEAN ground network provides the infrastructure for distributing the ADS-B surveillance- and other data received by the ground VDL4-specific radio stations to the interested users (ATSP facilities). The network consists of hierarchically organised local, regional and national servers. ADS-B reports received by any particular ground station can be recorded/ processed/ presented to the users anywhere in the ground network, as long as no filtering (except for removing "duplicates") is done between national servers.

2015

In addition to the AFTN- based message handling services, it may be expected that international ATN gateways and some national/ regional "native ATN" ATS Message Handling Systems (AMHS) will be deployed, being interoperable with the AFTN-based systems.
OLDI systems will expand and will encompass a significant part of European CAAs internal co-ordination activities. Additionally, in some areas the first ATN- based ICC systems may be expected.
VDL4-specific ground network will encompass the extended geographical area larger than the current NEAN area and will provide support for additional communications services.

2.3.2.3.1 Ground Support of AOC Data Link

An Airline Operational Control (AOC A/G data link is essential for the MA-AFAS project. The AOC data link will be used e.g. for the downlink of the aircraft position, uplink/ downlink of an AOC flight plan and different Collaborative Decision Making purposes.
With respect to the Airlines, it may be expected that following basic "airline types"- with corresponding communications end systems- will co-exist during the MA-AFAS time frame:

- ATN-oriented airlines
- ACARS-oriented Airlines
- Non-ATN/ Non-ACARS-oriented airlines

NOTE: At the time being no Airline participates in MA-AFAS, so only a very generic description of AOC systems may be provided.

The MA-AFAS aircraft itself will be ATN-compatible and also carry the non-ATN VDL4 communications equipment. There will be no support for ACARS communications within MA-AFAS trials.
The communications infrastructure options for AOC communications are indicated in the Figure 2.

2005

ATN-oriented airlines are expected to deploy ATN End Systems-ESs. The existing ACARS character-oriented data link user applications will be ported to become bit-oriented. An ATN ES would comprise the Generic ATN Communications Service (GACS) Application Service Element (ASE) within the Layer 7 of the ATN stack. In addition to the ATN ES, an ATN-oriented airline will also deploy an ATN G/G BIS router as an access node to the global ATN network.

NOTE: The Boundary Intermediate System (BIS) router is capable to perform ATN routing between distinct ATN domains. Specially, an Air-Ground (A/G) BIS defines the boundary between fixed and mobile ATN subnetworks. Each ground ES wanting to communicate with an ATN-capable A/C must have access- via G/G ATN infrastructure- to the appropriate A/G BIS router. With respect to the AOC communications, the required A/G BIS will be deployed by the communications Service Provider (SP).

NOTE: As an aircraft represents an ATN domain, it must also carry an A/G BIS router which is typically integrated within the Communications Management Unit (CMU).

However, not all A/C of an Airline will be ATN-compatible. For the part of the fleet using the ACARS protocol ATN may be used instead of the legacy Synchronous Link Control (SLC, Type-B messaging) as an access protocol between the AOC and the ACARS Data link Signal Processor (DSP). This assumes that the ACARS Service Provider (SP) deployed a G/G BIS router and an ATN/ACARS gateway is co-located with the DSP. In turn, the DSP would route AOC messages over an existing SP's ACARS network toward the appropriate ACARS Remote Ground Station (RGS).

Airlines which prefer to continue to use legacy ACARS data link would retain their existing host architectures, character-oriented user applications, as well as the legacy messaging protocols over SP's ACARS access networks. Such an ACARS-oriented AOC ES still may access ATN-oriented MA-AFAS A/C, assumed the conversion of the ACARS A/G protocol to ATN has been performed. This may be supported via the combination of the ACARS/ ATN gateway and the ATN G/G BIS router located at the DSP.

For MA-AFAS A/C it is in all cases necessary to establish the path over SP's global Wide Area Networks (WAN) between an AOC ES and the SP's A/G BIS router. The router in turn has the capability to interface with mobile VDL2/ VDL4 ATN subnetworks.

NOTE: This assumption does not preclude that -as indicated on the Figure 2*- an ATS Provider also configures his A/G BIS as a "transit" router for the AOC traffic. It is questionable whether the ATSPs would accept such an arrangement- it is more probable that the ATSPs will initially use the SP's A/G BIS router for their ATS data link traffic!*

Some (European-) airlines indicated their interest to use the VDL4-specific AOC data link instead of ATN data link. Such airlines would need to deploy the VDL-4 specific ESs and to adapt their existing AOC user applications. For the global access to the VDL4- specific network the TCP/IP protocol may be expected (there are ongoing SP's actions to provide support for TCP/IP in their WANs), so the AOC ES would have to be followed by an IP router. To access the VDL4 Ground Stations, the SP's WAN may be interconnected with the ATSP's regional TCP/IP WANs, finally an IP router would be required at each VDL4-specific ground station.

As the ACARS system will continue to be used and additional (ATN, VDL4-specific) communications will evolve, the Airlines will by 2005 be able to select from several types of End Systems and access protocols. They could also use several systems in parallel for some time. The deployment of Airline- owned ACARS/ ATN gateways and G/G BIS routers would support the migration from ACARS to ATN and also the development of new ATN-oriented AOC user applications.

2015

By 2015 it may be expected that the ACARS system will still be available, but the majority of the AOC traffic would use ATN because of "added values" like encryption and end-to-end transport service.

The Airline's decision to deploy VDL4-specific ESs will depend on the further development of the VDL4-specific network which is expected to proceed on the regional basis.

2.3.2.3.2 Ground Support of ATS Data Link

The MA-AFAS themes heavily rely upon the availability of the ATS A/G data link.

Within 4D-Enroute theme the ATS A/G data link will be used for the negotiation of 4D trajectories, approach profiles, departure routes and take-off slot times between an aircraft and the ground ATC system. Downlinked 4D trajectories will also be used for monitoring the fully autonomous aircraft by the ground ATC system, as well as for the uplink of the weather information.

Within the CDTI/ASAS theme the ground detection of conflicts will be enhanced by the downlinked aircraft parameters. The airborne situation awareness will be enhanced by uplinking the TIS-B information, the A/G data link will also be used to improve the airborne planning by providing the ATC constraints/ information about the additional airspace which could have been made available.

The TAXI theme uses the A/G data link for the delivery of taxi clearances, taxi routes, negotiation of off-block times, take-off slots, gate allocation, and also in support of the ground CDTI (TIS-B uplink).
With respect to the ATS data link, it may be expected that following basic "data link types" will co-exist during the MA-AFAS time frame:

- ATN data link
- ARINC 623/ACARS data link
- Non-ATN/ Non-ACARS data link

ATN-compatible ATSP ESs will include the support for the Application Service Elements-ASEs (CM, CPDLC, FIS, ADS) of the CNS/ATM-package 1. Such ESs will be interconnected with other ATS data systems (e.g. FDPS) hosting the end user applications which make use of the A/G data link services (e.g. FLIPCY, D-ATIS).

NOTE: Not all ASEs must be implemented at a particular ES, the selection will depend upon the scope of operational services the particular ES is aimed to support.

NOTE: The CM ASE and the corresponding DLIC service may initially be required at each ATSP's ES. Such "isolated" DLIC servers may later be replaced by the "centralised" DLIC server.

NOTE: Many options are possible with respect to the ATSP's ATN architecture. Here one topology has been described which is close to the ACCESS Study recommendations.

The communications infrastructure options for ATS data link communications are indicated in the Figure 2. Each ATN ES is attached to the G/G BIS of the corresponding ATSU (TWR, APP or ACC) which in turn has access either to the ATSP's or the SP's A/G BIS. The A/G BIS generally provides access to mobile ATN subnetworks like VDL2, VDL4 or SATCOM/ Data3 service. Bigger European airports will make use of initial ACARS-oriented airport data link services (DCL, D-ATIS), the Oceanic Control units will make use of the data link Oceanic Clearance Message (OCM) service. These services require dedicated ESs to be deployed, hosting the AEEC 620/622/623 stack. The ESs interface with the SP's ACARS DSP over SP's G/G networks. In Europe the Direct Host Protocol (DHP) over an X.25-compatible network is typically used as an access protocol.
For some purposes the ATSPs may also deploy VDL4-specific ESs. An VDL4-specific ES represents a gateway between the local ATS system hosting the user's applications and the VDL4-specific subnetwork. In example, TIS-B and FIS-B data will be sent over an TCP/IP based network towards the broadcast interface of the selected VDL4- specific Ground Station (VDL4_S GS), while the CPDLC- and similar messages will be directed towards the specific point-to-point interface of the selected VDL4 GS.
The TCP/IP based NEAN ground network currently supports the distribution of the ADS-B surveillance- and other data received by the ground VDL4-specific radio stations to the interested users (ATSP facilities). The network consists of hierarchically organised local, regional and national servers. Transmitted ADS-B reports received in any ground station can be recorded/ processed/ presented to the users anywhere in the ground network, as long as no filtering (except for removing "duplicates") is done between national servers.
It may be expected that similar infrastructure could be used for the regional distribution of the TIS-B data. Some TIS-B systems may also be deployed on the local basis, e.g. to provide support for CDTI on the Airport surface by using "local" VDL4 broadcast Ground Stations.

NOTE: It may be expected that the support required for operational broadcast and point-to-point A/G exchanges over VDL4- if not already covered by existing NEAN/ NUP network protocols- will become available in the near future.

With respect to the deployment of the D-FIS services (including D-ATIS), several data link server options are possible. One dedicated D-FIS server could be implemented at each bigger airport or TMA (this, however, would increase the complexity of the ground DLIC-server). Alternatively, national- or regional D-FIS servers could collect ATIS and other FIS data from all Airports within the region of interest, providing the data to the airborne users over ATN, ACARS or VDL4 broadcast. The second solution requires high capacity D-FIS server and increases the data traffic over the ground network between the server and Remote Ground Stations.

NOTE: While all three technological options (ATN, ACARS, VDL4-broadcast) are possible in the long-term, currently the main efforts in Europe are directed toward the D-ATIS deployment over ARINC 623/ ACARS.

2005

As the expectations from ATN are primarily located in En-route area, the ACCs and APPs will be the first ATSUs to be equipped with ATN ES and using the operational data link services. It may be expected that the most ATSPs will initially use the SP's A/G BIS (which handle both AOC- and ATS traffic).
At this time the TWRs in Europe will continue to use initial data link based on the ARINC 623/ ACARS. Some TWRs and ACC/APP units may also use local VDL4-specific ESs and services (e.g. for taxi guidance, enhanced surveillance, TIS-B, FIS-B).

2015

While the ATN deployment in the ACC/APP area will continue, it may be expected that some TWR ATN ESs will also be deployed, supporting airport-specific ATN-compatible operational services. The number of TWR VDL4-specific ESs will also increase. Additionally, it may be expected that increased number of ATSPs will deploy their own A/G BIS routers, thus separating the AOC messages from the ATS data link traffic.

2.3.2.4. Data Communications- A/G DL Infrastructure

NOTE: This chapter describes the communications infrastructure beyond the Ground BIS, as well as non-ATN subnetworks.

The A/G DL infrastructure options are indicated in the Figure 2.

- **Basic**

Currently, the ACARS-based A/G data link is used for both AOC- and initial ATS communications. The ACARS protocol runs between the A/C Management Unit (MU) within an Aircraft and the ACARS DSP. The ACARS system was enhanced in Europe for ATS purposes by adding the ARINC 620/622/623 protocols. The ground part of the ACARS subnetwork comprises the DSP and typically hundreds of VHF Remote Ground Stations (RGS) and user's access points interconnected via SP's global WANs. On the A/G interface an ACARS RGS currently uses a DSB-AM transceiver with in-band FSK modulation and Carrier Sense Media Access (CSMA) protocol, providing 2400 kB/s raw bit rate per each VHF channel (several VHF channels may be allocated, each providing ca. 300 B/s net throughput). On the ground side the transceiver is followed by the computer acting as in-band modem and providing a network interface(X.25). The DSP is additionally connected with several SATCOM Ground Earth Stations (GESs), allowing for the exchange of ACARS messages by using the SATCOM/ Data2 protocol.

- **MA-AFAS**

The A/G data link, as currently specified, allows for the data transfer between End Systems (ES) located onboard aircraft and on the ground. The ground ESs are in turn located either at an Airline (AOC) or at the ATS Provider's (ATSP) facilities.
In the ATN environment, A/G subnetworks are spanned between an airborne A/G BIS router and the ground-sited A/G BIS. The ground part of the subnetwork architecture depends on the subnetwork(s) used.

NOTE: MA-AFAS will support VDL2 and VDL4 ATN subnetworks. Mode-S-, SATCOM and VDL3 ATN subnetworks are outside the focus of the project.

2005

Due to the limited VHF radio coverage an A/C moves between dozens of VDL RGSs during each flight.
The ACARS SPs are currently replacing "Plain old ACARS" (PoA) RGSs by the new generation RGSs. These "bi-lingual" RGS will simultaneously support ATN VDL2 protocol and non-ATN AoA protocol on the same frequency, while continuing to provide support for PoA on dedicated frequencies.

NOTE: VDL2 technology uses digital D8PSK modulation and is capable to interface with ATN. AoA uses lower layers of the VDL2 protocol stack, but is not ATN-compatible *as it does not make use of an ATN internet. "Bi-lingual" RGS architecture will allow for a part of the ATN VDL2 stack to be used in support of AoA .*

The lower VDL2 protocol layers are hosted by the physical radio transceivers, the higher layers- including the network access- are hosted in a dedicated on-site computer.
ATN- and AoA network protocols are different (the RGS will internally have to implement the necessary interworking function), but the RGS network interface will in all cases use X.25 access. In an ATN environment each RGS must be connected to at least one A/G BIS. While there are clear SP's intentions to deploy their own A/G BISs in the short time (ARINC/ FAA, ARINC/ PETAL IIe), the availability of ATSP's A/G BISs is not easy to estimate, so it will be assumed that by 2005 only the SP's A/G BISs are available and used for both AOC- and ATS data link. On the longer term other arrangements are also possible, e.g. SPs using ATSP- owned private X.25 networks for the access to the SP-owned VDL RGS.
Currently there are no known SP's intentions to provide global ground support for VDL4 ATN subnetwork and the VDL4 standardisation (as an ATN subnetwork) has not been finished yet. It may therefore be expected that no global ATN-compatible VDL4 ground coverage will be available by 2005.
However, regional VDL4-specific architecture may be well available at that time (NUP). It could be used for non-ATN ATS data link broadcast, ATS point-to-point services and also AOC services. VDL4-specific GS consists of an VDL4 transceiver with associated GPS receiver, Site server and an IP router. The Site server terminates the VDL4-specific broadcast- and point-to-point A/G protocols and supports G/G data exchanges with remote VDL4-specific ESs over the TCP/IP based WAN.

2015

It is possible that by that time the ATSPs also deployed their own VDL2 RGSs and A/G BIS routers which may or may not be dedicated to the ATS traffic.
While the SPs will further provide support for AoA, it may be expected that by 2015 there will be no support for PoA communications anymore. The VHF frequencies being formerly used for Plain Old ACARS may by 2015 become available either as additional AoA channels or for the ATN VDL2 data link.
It may be expected that by 2015- in addition to the existing VDL4-specific interface- at least on regional basis an ATN-compatible VDL4 access could become available. The existing European NUP infrastructure could be upgraded to become ATN-compatible. Alternatively, dependent on the outcome of the VDL4 standardisation the SPs may decide to provide global ground support for VDL4 as an ATN subnetwork.

NOTE: The capacity and performance of an VDL2 ATN subnetwork is higher than the capacitiy provided by ACARS, but because of the CSMA access protocols, lack of the subnetwork priority, non-gradual network congestion and other factors still insufficient for the most critical ATS data link applications. It is anticipated in several studies and projects that higher performance long-term VDL subnetwork solution would be required, VDL4 and VDL3 being the most realistic candidates.

2.3.2.5... Data Communications- A/A DL

- **Basic**

Currently, as the ACARS data link does not support A/A data communications, the voice remains the only pilot's means to exchange the information with another pilot. This can be done without any ground support.

- **MA-AFAS**

Within MA-AFAS, VDL4-specific broadcast data link will be intensively used for different purposes, including the exchange of the position- and intent information by using ADS-B communications service. While this again does not require any ground support, the ground surveillance systems may optionally benefit from the reception of the ADS-B information. Currently ADS-B information is on the trial basis distributed to the interested users through the NEAN network which is capable to use any standard IP-based WAN or LAN technology as long as a TCP layer is provided as transport mechanism. NEAN network uses hierarchical architecture based on local/ regional/ national servers which concentrate-, filter- and distribute ADS-B information received over different RGSs.

NOTE: There are also some other means/ technologies suitable for the A/A data exchanges: Universal Access Transceiver (UAT) and Mode S extended squitter. These technologies are however outside focus of the MA-AFAS project.

2005- 2015

It may be expected that the NEAN network will be expanded (NUP) and the scope of the communications services provided by the network will be extended (currently only two services are supported, a real-time data-acquisition service for collecting ADS-B position reports and unconfirmed end-to-end message service). In the Figure 2 the high-level ground communications architecture which may be expected by 2015 has been outlined, including the AOC End Systems, ATS End Systems, ATN G/G BIS routers, A/G BIS routers, IP routers, different access networks (ATN-, ACARS, TCP/IP) and radio communications resources (SATCOM GESs, VDL2 RGS, ACARS RGS, VDL4 GS, VDL4-specific GS). The shaded parts of the architecture are outside the scope of MA-AFAS project.

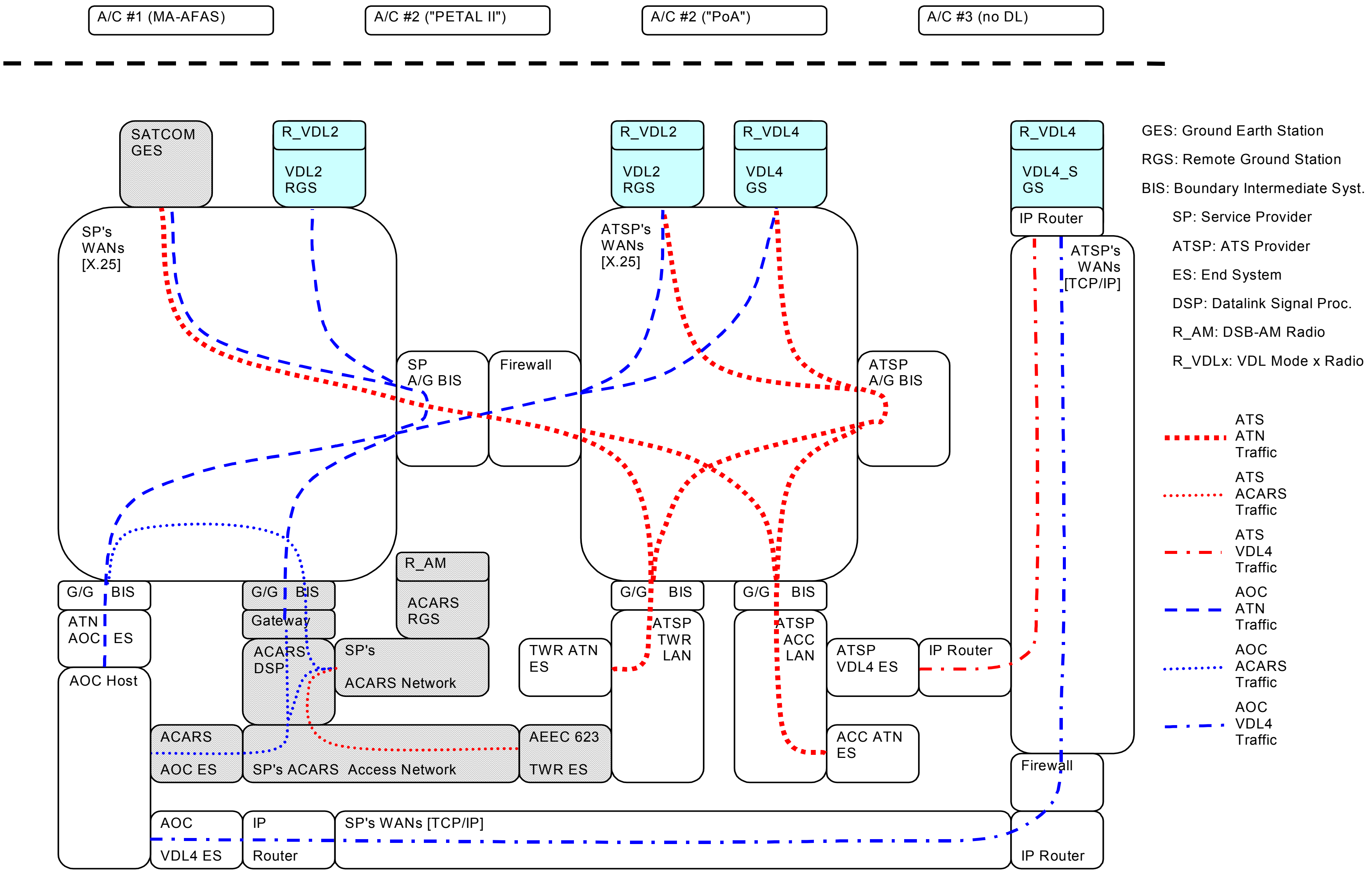


Figure 2 : Ground Network Architecture for MA-AFAS Trials

2.3.3 Navigation (NAV)

This chapter describes the navigation systems used, including brief descriptions of the G/G communications used in support of such systems.

The description is based on the EUROCONTROL "Navigation Strategy for ECAC" document (NAV.ET1.ST16-001, Ed. 2.1, 15.03.1999).

2.3.3.1. General

- **Basic**

Currently a mixture of different navigation systems is deployed in Europe and used by the civil aviation. In the En-route area NDB, VOR, DME/ TACAN, as well as GPS systems are used. These systems are also used in the TMA/ Airport areas during Departure- or Approach/ Landing flight phases, respectively, and are augmented at the Airports by the ILS CatI/II/III systems.

2005

While the DME and GPS systems will continue to be fully supported, the process of rationalisation of the ground navigation infrastructure will result in a reduced availability of the En-route NDBs and VORs. At the same time there will be no significant reduction for TMA/ Airport NDBs. At Airports ILS Cat I/II/III systems will continue to be used. SBAS will be fully operational over ECAC, providing sufficient performance for the use of RNAV in en-route and TMA environments. By giving good vertical guidance, SBAS will also support near CATI precision approach operations.. At the same time the initial deployment of the MLS Airport systems may be expected at some locations. Due to the low system error of SBAS systems, a major factor in the accuracy of navigation is the geodetic datum used. WGS84, the geodetic datum used by GPS, has been mandated by ICAO since January 1998 for use for the surveying of all aviation facilities/obstacles. Introduction of GRAS may be expected within the NUP area.

2015

There will be little support for the navigation based on NDBs and VORs for both En-route and TMA/ Airport operations. Multi-DME and GNSS2 will continue to be fully supported for en-route and TMA operations.While the use of ILS systems will be significantly reduced, MLS will continue to be supported at specific locations. Additionally, the full GBAS support for TMA/ Airport operations (inclusive Cat I/II/III operations) will be available over ECAC. Broader GRAS coverage may be expected.

- **MA-AFAS**

The Global Positioning System (GPS) is openly provided by the US DOD. However, in its raw form its performance does not meet the stringent requirements of civil aviation and therefore needs to be augmented to improve the accuracy, integrity, continuity and availability. ICAO have standardised two concepts for augmenting GPSto meet civil aviation requirements. These are:

- Space Based Augmentation System (SBAS), providing a wide area solution down to Category I precision approach minima and;

- Ground based Augmentation System (GBAS) providing a regional area solution down to Category III precision approach minima.

SBAS

In Europe, the SBAS system under development is called the European Geostationary Navigation Overlay Service (EGNOS).EGNOS will deploy an extensive network of GPS and

GLONASS monitoring stations, spread throughout Europe and beyond to maximise the number of satellites in view and to maximise the area for which the GPS/GLONASS signal's ionospheric error component can be calculated. The data is logged, and errors in the estimated position calculated by comparison with the known position. These errors are sent to a central processing facility, which calculates corrections. These corrections are then uplinked to geo-stationary satellites, which simply rebroadcast these corrections at GPS frequencies over the footprint of the geostationary satellite. This significant communications and processing infrastructure is invisible to MA-AFAS.

NOTE: No changes of the ground support for SBAS are required with respect to MA-AFAS, but MA-AFAS A/C must be equipped with an EGNOS-compatible receiver.

An aircraft with an EGNOS receiver will be able to access this satellite navigation system and have confidence that it will be providing the required performance. The stability of this system allows designers of interfaces to other equipment to avoid lengthy performance checks.

The output of an SBAS receiver is suitable for the driving of an ILS-lookalike display, and the performance and capabilities of SBAS allow new, simple approaches (with possibly lower minima) to be made to airports where no ground facilities exist, or which previously had complex non-precision approach procedures based on terrestrial radio beacons. There are significant safety benefits in replacing these complex NPA procedures. SBAS may permit lower minima than was possible with the previous complex NPA procedures. An SBAS equipped-aircraft will also be able to perform RNAV in the TMA, opening up new routes in to the approach. The benefits of SBAS are available throughout the large coverage area of the geostationary satellites. SBAS can support an unlimited amount of users through en-route and terminal, and provides an instrument approach capability. The supporting ground infrastructure is currently under development. The approach procedures for use with SBAS are stored in a database on board the aircraft.

GBAS

GBAS uses a monitoring station on the airfield to which the approach is being made. As with SBAS, the errors are calculated and corrections necessary for each satellite's pseudorange measurement processed. These corrections are then uplinked with a VHF link to all users within line of sight of the uplink station, up to approximately 30 miles. The approach procedures for use with GBAS are uplinked from the ground station and stored in a database on board the aircraft.

Thus the concept of operation is that SBAS will be used throughout the flight in most instances. For approaches to airports requiring Category II/III approach performance, the aircraft will change from using SBAS to GBAS as its navigation source at a known point during the approach. Studies are currently underway on how best to achieve this.

NOTE: It may be assumed that initial GBAS capability will be available by 2005 at selected airports and the full capability by 2015 .

Both SBAS and GBAS support RNAV, which makes use of waypoints, i.e. mathematically described points in space rather than distance/heading from a radiobeacon. ICAO has mandated that all of these waypoints should be stated in a common geodetic reference frame, WGS-84, (i.e. that used by GPS). Both SBAS and GBAS also support vertical navigation to varying degrees of accuracy.

At least one on-airfield GBAS will support approaches to all of the runways at that airfield. These approaches will be possible down to the most demanding application, namely autoland. GBAS will be available to substitute ILS systems that are suffering degradation due to FM interference and signal reflections near the approach. GBAS will also obviate the need for the lengthy flight inspection and regular re-calibration process associated with ILS systems. GBAS will also support new approach paths, which may be required for obstacle clearance

and noise avoidance. As with SBAS, the supporting infrastructure is invisible to the MA-AFAS concept.
An properly equipped aircraft simply can exploit GBAS as, with a suitable airborne receiver, it will have a full bad weather approach capability. The approach procedures for GBAS are broadcast in the uplink, and hence GBAS is independent of all other systems on-board the aircraft.

GRAS

GRAS operates in a similar manner to SBAS, in that a network of ground-monitoring stations calculate corrections. The difference is that these calculations are uplinked to the aircraft via a VHF system (VDL4) on the ground, as per GBAS. Whilst these corrections are intended to be available at distances further than those provided by GBAS, GRAS does not have the large coverage footprint of SBAS. Four GRAS service levels have been defined. Service Level 1 is intended for wide-area en-route coverage, it will use network of "overlaping" ground stations, each having approximatelly 200 NM range, to provide non-critical services (integrity check). Level 2 services- including differential corrections- will be provided in en-route and TMA (several ground stations), while Level 3 critical services will be provided in the vicinity of busy airports and on the airport surface. GRAS Level 4 is reserved for future critical applications.
Unless the datalink used is dedicated to GRAS, it may also not be able to support the broadcast of procedures.

2.3.4 Surveillance (SUR)

This chapter describes the surveillance systems expected to be used within MA-AFAS time frame. The description is based upon the EUROCONTROL "Surveillance Strategy for ECAC" document (ECAC Surveillance Strategy, Ed. 1.0, Jan. 1998).

- **Basic**

Currently the operational air traffic surveillance in Europe is mainly based upon the Mode A/C Secondary Surveillance Radars (SSR), with Primary Surveillance Radars (PSRs) providing (independent-) back-up.

2005

PSRs will no longer be used in the ECAC En-route airspace, but they will remain in use in TMA areas (as the only mean of detecting non-co-operative targets).
In the parts of the ECAC airspace with lower traffic densities outside the core area the existing Mode A/C systems will be upgraded to the Monopulse SSRs (MSSRs) capable to provide improved position accuracy.
In the ECAC core-area the Mode S will be deployed for the enhanced surveillance purposes, overcoming the problems with the shortage of Mode A/C codes and allowing for the downlink of aircraft parameters (DAPs) which in this area are required for enhancing the capabilities of the ground ATM systems.

NOTE: DAP denotes a group of A/G data link functions capable to present a set of aircraft-originated parameters to the ground ATM systems and/or controllers. DAPs may be transmitted both over ATN- and mode-specific A/G subnetworks (e.g. by using Mode S Ground Initiated Communications B-GICB- protocol) and are either directly used by the controller or by the advanced controller ATM tools (Monitoring Aids, Trajectory Prediction, Medium Term Conflict Detection, Short Term Collision Allert, Minimum Safe Altitude Warning, Area Proximity Warning e.t.c.).

In the areas without PSR/ SSR infrastructure like Mediterranean area or Atlantic Ocean, as well as for the low-level operations like off-shore oil fields the initial ADS-C or ADS-B-based surveillance system may become operational. 2015
PSRs will continue to be used in TMA areas.

In low-density areas the MSSRs will continue to provide sufficient performance and will not be replaced by the Mode S systems.

ADS-B will become the major element of the surveillance system in extended airspace (including the airport surface), but it is not expected it to become the sole means of surveillance in Europe until the GNSS system it relies upon becomes approved as a sole means of navigation. It is however expected to be used as a complement to MSSR or Mode S in low density-/ high density airspace, respectively, fulfilling the duplicated surveillance requirements by a mixture of ADS-B and MSSR (or Mode S).

> *NOTE: The ADS-B position is (within the VDL4 context) derived from the onboard GPS receiver.*

In low density areas without PSR/ SSR coverage and remote areas ADS-C may also be used instead of ADS-B.

> *NOTE: Although not described in the ECAC Strategy document, PSR/ SSR system will by 2005 and beyond make use of existing ground-ground data networks dedicated to the transmission/ distribution of the radar data (e.g. RADNET).*

> *NOTE: While ADS-C based system makes use of an ATN ground infrastructure, the distribution of the ADS-B data may require dedicated non-ATN networks (e.g. NEAN) to be deployed.MA-AFAS*

The MA-AFAS aircraft will by assumption be compliant with all ground surveillance requirements expected by 2005 and 2015, respectively. Additionally, due to its ADS-B capability it will be capable to provide its position-, intent and eventually some other data to other aircraft in all airspace types (En-route, TMA, Airport surface).

While in the core ECAC area the ground PSR/SSR surveillance will continue to be used (and will be supported by the Mode-S capable transponder onboard MA-AFAS aircraft), the surveillance in remote areas without PSR/ SSR infrastructure may now benefit from the MA-AFAS ADS-B function: the intent/ position data received by the "monitoring" ground VDL4 stations may be forwarded over an G/G network to the interesting surveillance units. In these units the ADS-B data may be processed/ presented to the controllers in the way similar to the presentation of the radar-based data.

Similarly, the ADS-C function (using SATCOM ATN subnetwork) may be used in combination with the ground ATN infrastructure in oceanic- and other areas without PSR/SSR or VDL4 coverage.

> *NOTE: Due to the limited VDL4 range (line of sight) the ADS-B messages cannot be received by the ground surveillance systems while an aircraft is flying over the ocean. It is also unrealistic to assume, that the monitoring VDL4 ground stations will be available in remote areas. As ATN-oriented ADS-C service may- in addition to VDL- also make use of the SATCOM subnetwork, the ADS-C reception may be guaranteed- within the lattitude constraints- even in such areas, thus extending the horizon of the surveillance systems.*

Both concepts may also be used as an independent overlay (and backup) to the PSR/SSR-based surveillance systems.

In particular in the Airport environment, the reception of the ADS-B position/ intent data would ease the unique identification of aircraft, conflict detection and monitoring of the compliance of the ground movements with taxi clearances.

2.4 Availability characteristics

2.4.1 Definition

The availability is used to define requirements on continuous system operation over a long period of time as well as the ability of a system to perform its required function at the initiation of the intended operation. It is quantified as the proportion of the time the system is available to the time the system is planned to be available.

2.4.2 ADS

The availability of the ADS system shall be 99.996%.

2.4.3 CPDLC

The availability of the CPDLC system shall be 99.996%.

The requirement for CPDLC system is up to the Communication Service Provider interface. It therefore includes the aircraft/ground based ATN End Systems and Transport layers. For non-ATN infrastructures it includes the equivalent to ATN internet and ATN Layers 5-7.

2.4.4 ODIAC Services

- **CIC (ACL)**
  The ATC Clearances and Information Service shall be available during all flight phases.
- **ACM**
  The ATC Communications Management Service shall be available during all flight phases.
- **DSC**
  The Downstream Clearance Service shall be available in all flight phases. The DSC service shall not be available with the C-ATSU when the aircraft has a C-ATSU link established (i.e. the CIC and DSC services shall not be simultaneously active with the same ATSU).
- **DCL**
  1. The Departure Clearance Service **shall** be available from a time period (see note) prior to the EOBT (or engine start-up request) until the time the aircraft commences movement under its own power.

     The time period will depend on many factors such as airport procedures, airline procedures, slot time, traffic density, SSR code allocation, ..it is advisable not to initiate a request more than 30 minutes prior to EOBT. Requests made shortly prior to EOBT, about 10 minutes, will be less likely to be revised.

  2. If local procedures permit, the departure clearance service **should** also be available from the time the aircraft commences movement under its own power until the aircraft leaves the holding point for the flight's take-off runway. The use will be restricted to revisions of granted clearances normally initiated by the C-ATSU.

     In applying the above described availability, consideration must be given to the different operational meaning of the services as follows :

     Operational use 1 (standard availability) :

     The aircraft is in the non-active flight phase (pre-flight).
     Air Traffic control is under the Ground movement planning phase (clearance delivery).

     Operational use 2 (extended availability) :

The aircraft is in the active flight phase (taxiing).
Air traffic control is in the Ground movement control Phase (Control of Aircraft moving on the apron and aircraft, vehicles, persons and obstructions on the maneuvering area).

- **CAP**
  The Controller Access Parameters Service shall be available in all phases of flight between take-off to landing. The required set of parameters to downlink and the periodicity of the data collection may change during flight

- **D-OTIS (ATIS, METAR, OFIS)**
  The Data Link Operational Terminal Information Service shall be available during all flight phases, either as a broadcast or as a specific request and delivery message, depending on availability, and for the broadcast version, on the actual position of the aircraft (within or out of range).

- **D-RVR**
  The Data Link Runway Visual Range Service shall be available during all flight phases.

- **FLIPCY**
  This is the Flight Plan Consistency Service.
  Service Initiation:
  The airborne planned flight plan might be downlinked according to 3 different modes :

1. Systematically and automatically before entering in a new ATS unit's area of responsibility;
2. In case of modification of the flight plan of the airborne navigation system by the aircrew:
   2.1.1. In case of en-route diversion, with modification of the destination airport;
   2.1.2. Acceptance of a route proposed by ATC through the Dynamic Route Availability (DYNAV) service;
   2.1.3. Insertion of additional waypoint(s) by the aircrew in the airborne navigation system.
3. On controller's special demand : the controller shall have the possibility to manually request the airborne flight plan for an unexpected check in case of doubt about the progress of a flight.

Service Termination:

The service termination occurs when the aircraft leaves the ATS unit's area of responsibility or if starting a STAR procedure.

- **DYNAV**
  Service Initiation:
  The Dynamic Route Availability service might be initiated at any time during the progress of the flight in the ATS unit's area of responsibility.
  Service Termination:
  The service shall be terminated as the flight in progress leaves the ATS unit's area of responsibility or is starting an approach procedure.

- **D-SIGMET**
  The Data Link Significant Meteorological Information Service shall be available during all flight phases.
- **PPD**
  The Pilot Preferences Downlink Service might be initiated and terminated at any time during the progress of the flight in the ATS unit's area of responsibility.

- **COTRAC (Preliminary definition of BASIC COTRAC)**
  Service initiation **:**
  The Common Trajectory Coordination Service might be initiated in the first en-route control sector along its flight trajectory.

  Service termination:

  The service might be terminated when the aircraft exit from the last en-route control sector along its flight trajectory.

- **DLIC**
  The Data Link Logon Service shall be available during all flight phases.

- **COSEP**

The service might be initiated and terminated at any time during the progress of the flight in the ATS unit's area of responsibility.

2.5 Volume characteristics

2.5.1 Introduction

The purpose of this chapter is to give an estimate of the maximum volume of the data link traffic produced by the MA-AFAS aircraft.
While the traffic produced by the MA-AFAS aircraft is of prime interest, other aircraft categories with different communication capabilities will also be present within the same airspace and will use the same communications channel. This "background traffic" may have to be simulated during at least some of the validation steps.
The detailed simulation of the data link is a complicated task. It requires that all the services with associated parameters (data content, number of occurrences, intermessage times, QoS requirements...) are characterised, the aircraft entry times into selected airspace-, dwell times and spatial distribution are defined, as well the complete information about the air-ground sub-network is available (e.g. location of the ground VDL stations, access network topology/ performance, concept/ location of the DLIC servers, A/G BIS routers, End Systems...). Additionally, radio channel propagation characteristics must also be known for each selected environment (Airport, TMA, En-route).

2.5.2 Method Description

The approach proposed here aims to determine the "average data density"- produced by an A/C while executing dedicated communication pattern.

2.5.2.1. Traffic Patterns

Several traffic patterns have been developed on "per flight" basis as applicable to different aircraft "capabilities" and different time frames (2005/ 2015).
The patterns have been derived from the "Future VHF Study" (EUROCONTROL COM.ET2.ST12) simulation scenarios for the busy airspace around the Frankfurt Airport. Currently, the patterns include ODIAC services, AOC services, ATS broadcast services and provisory 4DTN services. The number of service invocations for ATS services was agreed with the DFS controllers and relies upon current voice practices and other available sources.

Some CPDLC Airport services- not being covered by ODIAC- have also been included (Pushback-, Taxi-, Line-up-, Take-off clearances), assuming that the procedure will be similar to the ODIAC CIC (ACL) service.
A set of provisory 4DTN dialogue services have been included as a replacement for the (at this time still immature-) COTRAC service.
Two types of the SAP service: SAP-Flight and SAP-Meteo have been included (this service also has a status of "future work" by ODIAC).
Several AOC services have also been included into scenarios (except PDC/ ATIS/ TWIP which were believed to be mutually exclusive with related ATS services) and quantified according to the ARINC DRAFT AOC Traffic Model (1996).
One DLIC/ Logon transaction per ATSU has been foreseen in all patterns. It has been assumed that each involved "ATSU"- TWR, APP, ACC/ UAC control- has its dedicated A/G BIS router and the DLIC server,

NOTE: Assumed that the whole MA-AFAS airspace could be served by a single A/G BIS router and a single DLIC server, some DLIC transactions could be reduced, but the impact on the total channel loading would not be significantly changed!

Specifically for the MA-AFAS purposes, some additional services have been added to the patterns:

- DSC Downstream Clearance
- A/A_PTP A/A Point-to-point Messaging
- ADS-B ADS Broadcast
- TIS-B Traffic Information Service Broadcast
- FIS-B Flight Information Service Broadcast
- DGNSS-B DGNSS Broadcast (GRAS)
- ADS-C ADS (event-, periodic-, demand contract)
- PPD Pilot Preferences Downlink

2.5.3 Inputs

2.5.3.1. Airspace

The total airspace volume of interest (the total number of airports, TMAs and ACC/ UAC sectors which share the communications resources- e.g. VDL channel) must be defined.
The representative traffic patterns have been trimmed to the Frankfurt Airport, Frankfurt TMA and FIR Frankfurt ACC/ UAC sectors. The patterns are related to the MA-AFAS flight phases as follows:

- CTR = Airport surface (before push-back to take-off, from landing to gate)
- TMA = Terminal (climb/ descent+ initial approach)
- En-Route = ACC/ UAC sector (cruise)

The CTR and TMA scenarios are different for each flight direction (DEP = Departure, ARR = Arrival). All flights within ACC/ UAC sectors have been assumed to produce basically the same data link traffic pattern.

2.5.3.2. Average Aircraft Dwell Time

The aircraft (average) dwell time within a given airspace type will influence both the number and the detailed content of the communications transactions and must be defined separately for each airspace type and each direction.

2.5.3.3. Aircraft Population

The total number of A/C which are simultaneously active (visible) on the communications channel (within the maximum communications range) must be determined for each airspace type (CTR, TMA, ACC sector) and each direction (DEP, ARR) within the total airspace volume determined above.

2.5.3.4. Capability Mix

With respect to the data link traffic, it is necessary to separate the complete aircraft population found in each airspace type into dedicated classes dependent on the supported communications capability. Four such classes are proposed below:

1. The "AOC DL-only" aircraft, equipped with an (ACARS) AOC DL, but without support for the ATS DL services (current situation, such an A/C uses voice for all ATS purposes).
2. The "Basic DL capability" aircraft, supporting both ATS and AOC data link, but without 4DTN or ASAS capability.
3. The "4DTN- capable" A/C, supporting the "basic" capability, additionally capable to negotiate/ fly 4DTN trajectories, but without the CDTI/ ASAS capability.
4. The "Free-flight- capable" A/C, carrying the CDTI/ ASAS equipment, being also "4DTN-capable".

The "capability mix" may be different in different airspace types. Each category will by assumption produce its dedicated communications pattern. Because of the assumed backward compatibility the patterns e.g. for the 4DTN- or Free-flight capable A/C already include the "basic" services. Different patterns have been proposed for the years 2005 and 2015, respectively, additionally the number of transactions has been adjusted (increased) for some services by 2015.

NOTE: MA-AFAS A/C may be associated with multiple capabilities, dependent on the current flight phase and the concept (e.g. could be associated with "Free-flight" when flying in UAC sectors, with "4DTN" while transiting through the ACC/ TMA, with "Basic" in the CTR airspace. Non-MA-AFAS A/C with different capabilities will also co-exist within the same airspace!

2.5.3.5. Average Data Content Produced by an A/C

An average amount of data exchanged for each service (in Bits) has been estimated (including uplink/ downlink transactions and logical acknowledgements, from the Future VHF Study).

According to the selected capability/ airspace/ direction/ time frame, certain number of appropriate data link services will be executed (according to the selected pattern) for a given A/C within the "dwell time" t_DW and certain total amount of the information (in Bits) pertinent to this A/C would be generated and presented to the communication channel.

NOTE: The calculation of the total data content is different for event-triggered/ periodic/ deterministic services.

The data volume produced by the single A/C within t_DW can be approximated by the continuous data stream having an "average data density" (in B/s).

2.5.3.6. Merging Different Patterns

By summing-up the contributions of all A/C using different patterns in different airspace types, the total information density may be calculated as expected in the MA-AFAS scenario.

NOTE: By comparing this information density with the estimated channel net capacity (B/s) it will be possible to decide whether the channel a-priori capacity is sufficient for the intended aircraft population.

NOTE: For the simulation purposes, the contributions of non-MA-AFAS aircraft coud be determined separatelly and added to the "real" MA-AFAS traffic as "dummy messages" with the corresponding average density.

2.5.3.7. Parameters/ Figures

The following tables summarize the inputs required for the estimate of the traffic volume:

	2005	**2015**
Total number of Airports in MA-AFAS scenario		
Total number of TMAs in MA-AFAS scenario		
Total number of ACC/ UAC sectors in MA-AFAS scenario		
Average dwell time t_DW [min] of departing A/C (Airport)		
Average dwell time t_DW [min] of arriving A/C (Airport)		
Average dwell time t_DW [min] of departing A/C (TMA)		
Average dwell time t_DW [min] of arriving A/C (TMA)		
Average dwell time t_DW [min] of A/C in an ACC/ UAC sector		

2005	**Departing**				**Arriving**				**Total**			
A/C Capability (1/2/3/4)	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Average number of Aircraft on each Airport's surface												
Average number of Aircraft in each TMA												
Average number of Aircraft in each ACC/ UAC sector												

2015	**Departing**				**Arriving**				**Total**			
A/C Capability (1/2/3/4)	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Average number of Aircraft on each Airport's surface												
Average number of Aircraft in each TMA												
Average number of Aircraft in each ACC/ UAC sector												

NOTE: The A/C Capability (1/2/3/4) refers to the capability definition from the chapter "Capability Mix".

2.5.4 Table Items

The following candidate traffic patterns are provided (separately for 2005/ 2015) in the form of an EXCEL worksheet:

- CTR/DEP
- CTR/ARR
- TMA/DEP
- TMA/ARR
- ACC Sector

Here is a brief description of the structure of the table.

2.5.4.1. Service_ID

Unique identification of the (part of the-) service in the pattern. ACM/V and ACM/M describe different messages of the same ACM service. D-ATIS (D-RVR, D-SIGMET) denotes the first request/ delivery, the suffix _U refers to the subsequent update(s). ADS_1_PC denotes the ADS periodic contract, the corresponding periodic reports are denoted by ADS_1_PR. Similarly, ADS event contract/ report are denoted as ADS_1_EC and ADS_1_ER, respectively. The prefix 4D_ denotes different sub-cases of the 4DTN (COTRAC) service.
Some services (ACM, CIC...) may have multiple instances (within the pattern) which are separately quantified.

2.5.4.2. ODIAC Service

Services being proposed by ODIAC have been separately marked.

2.5.4.3. Service Description

Brief description of each service.

2.5.4.4. Single Service Average Data Content

Average data content of the single service invocation in Bits (averages of the estimated min/ max values for each message, summed across all application messages and technical acknowledgements).

NOTE: This data volume is related to the user payload and does not include the overhead due to the subnetwork-specific protocol stack!

2.5.4.5. Transactions Per A/C

2.5.4.5.1 Total

Total number n of Voice- or Data service transactions expected per A/C within given dwell time t_DW. Initial estimates for the most data link services have been obtained from the current voice practices. Other "new" ATS data link services have been "mapped-back" to the voice transactions (by using ODIAC descriptions of the procedures with/ without data link). For such data services only the initial estimates have been made in the table.
The inspection of different A/G data link service categories has shown that three basic groups exist:

- services triggered in a deterministic way (e.g. only once per flight)
- periodic services (being characterised by the period TP)
- event-triggered services (being characterised by the intermessage time TI)

For event- triggered services "Total V/DL" corresponds to n= t_DW/ TI, where t_DW is the dwell time and TI is the average intermessage time.
For periodic services "Total V/DL" corresponds to n = t_DW/ TP, where t_DW is the dwell time and TP is the period.
For deterministic services (e.g. DLIC) n has a fixed value.

NOTE: The parameter "n" in the table can be calculated after the dwell times t_DW have been estimated for all airspace types!

2.5.4.5.2 Probability_V

Probability [0...1] that a given service will be executed by using Voice procedures.

2.5.4.5.3 Probability_D

Probability [0...1] that a given service will be executed by using Data link procedures.

2.5.4.6. Total Data Density Within t_DW

Total data density per service (number of bits/ dwell time t_DW). Applicable only to the Data link services. Calculated as
(Single Service Av. Data Content) x (Total V/DL) x (Probability_DL) / t_DW.

2.5.4.7. Comments (DL)

Different comments, describing e.g. the assumed values for TI/ TP parameters.

2.5.5 Further Explanation of The Traffic Patterns

While the Basic scenario is believed to be applicable to both the year 2005 and 2015, 4DTN and Free-flight are not expected by 2005, so the corresponding columns for 2005 have only been indicated-, but not populated in the table.

> The sequences in the table do not strictly follow the actual sequence of events which would be executed during the flight. However, it has been recognised that some services depend on each other (e.g. the pushback clearance is issued after the DCL= ATC clearance), while the others may be independently triggered.

For some services additional assumptions/ parameters (mainly the mean inter-message time TI and the message data volume) are required, as indicated in the table.
Services from the table have been roughly associated with the MA-AFAS themes (indicated in the table by different background colour).
The DGNSS-B service may be provided on a separate channel (transparent to MA-AFAS), but also on the shared VDL channel (GRAS).
The FIS-B G/A broadcast services is non-saturable (e.g. not dependent on the number of Aircraft flying in the airspace of interest). The data traffic volume generated by the FIS-B service should be added to the total volume obtained for all other broadcast services (ADS-B, A/A point-to-point messages) deployed over the same VDL channel.
It has been assumed that the Free-flight capable A/C does not generate TIS-B position data. In turn, the total amount of the TIS-B broadcast information will be dependent on the total number of A/C not equipped with the ADS-B. The information contribution of each non-ADS-B A/C to the total TIS-B data has been assumed to be comparable with the ADS-B position report. On the contrary, by assumption only the Free-flight capable A/C will generate ADS-B position reports.
CIC (ACL) service has not been used in 4DTN and FF patterns: as long as there is no conflict situation, an A/C would- according to the PHARE scenarios- fly along the agreed trajectory without a need for additional clearances. Should the A/C, however, enter the conflict situation, there would be no time to use the CIC/ ACL- the voice communications would be used instead! The similar rationale would be applicable to the FF scenario.

3 MA-AFAS User Application Description

3.1 CDTI/ASAS applications

ASAS Spacing applications are expected to be applied in En-route and TMA Managed Airspace, by 2008. This application is expected to respond to air traffic growth by developing close co-operation between the ground and airborne sides of ATM.

3.1.1 In-descent Spacing

3.1.1.1. Operations service description

This longitudinal spacing application consists of delegating the spacing task from controller to flight crew in terminal area. Consequently the aircrew has to maintain a horizontal spacing behind the target aircraft. This spacing task is delegated to aircrew with suitably equipped aircraft. Aircraft are sequenced by the controller, in order to prepare the final approach. The flight crew is tasked to acquire and maintain a given spacing (distance or time-based) with respect to a preceding aircraft (the target), assisted by onboard equipment.

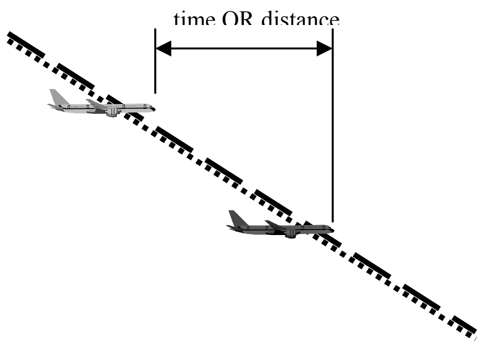


Figure 3 : Distance or Time-based spacing

This application provides a tool in order to alleviate the controller workload. This is an application of ADS-B/CDTI and requires both new air and ground-based procedures.

This application can be seen as an extension of the successive visual approach clearance in today's control. Where weather conditions permit and the aircrew has reported the lead aircraft in sight, the controller may instruct a successive visual approach between a stream of aircraft (this shifts the traffic spacing tasking to the aircrew).

It should be noted that the separation assurance is still the responsibility of the controller.

The controller is still responsible for keeping other traffic (not under In-descent Spacing application) separated from the aircraft involved in the application.

To conduct this application the following elements are used on board the spacing instructed aircraft:
- If the target aircraft is ADS-B equipped, information on the target is collected by this means. If the target aircraft is not ADS-B equipped, target's state vector and other information may be provided by TIS-B.
- A CDTI will be used to allow the identification of the target aircraft as well as to allow the spacing task.

The following elements are used on the ground:

- It is expected that the main means of surveillance will remain to be radar-based for the foreseeable future, however if a ground ADS-B infrastructure is implemented, it could be used for surveillance.
- TIS-B infrastructure may be required to conduct the application to support mixed equipage (i.e., some aircraft ADS-B equipped and some not equipped), or as a backup surveillance mean.

Voice communications are the primary communication link, data link communication could be used if available. Aircrew/controller communications involve new phraseology for the application for voice, or new datalink exchanges.

3.1.1.2. Scope and Objective

The operational objective of the In-descent Spacing application is to provide a new tool for the controller to help in his separation assurance task. This tool involves the flight crew through a new form of co-operation.

The In-descent Spacing application is not limited strictly to TMA sectors, it may initially be applied in the extended TMA (transitional en-route) airspace, where the aircraft is under ACC control (i.e., immediately after the Top of Descent point). The In-descent Spacing application is intended to be used from the initial descent (usually an extended TMA under ACC control) down to final approach, e.g. at the FAF (TMA under APP control).

The In-descent Spacing objectives are to accomplish the following:

a) Apply more regular spacing.

b) Increase extended TMA capacity.

3.1.1.3. Expected Benefits, Anticipated Constraints, and Associated Human Factors

3.1.1.3.1 Expected Benefits

- Reduced controller workload (by streamlining the controller task).
- Depending on the number of spacing instructed aircraft, improvement in the arrival sequence management can improve the (extended) TMA capacity
- Increased the aircrew Situation Awareness concerning the target,
- It is expected that, having aircrew in the "loop", improving aircrew situation awareness and increasing controller availability, the level of safety should be improved or at least maintained.

Additionally, the application could reduced voice frequency congestion (with or without data link);

3.1.1.3.2 Anticipated Constraints

- Special care must be taken to insure that the In-descent Spacing application will not entail a significant increase in aircrew workload. A sufficient level of assistance must be defined.
- Mixed equipage could reduce application effectiveness (when a certain percentage of the traffic are not suitably equipped for this application)
- Aircraft involved in the application must be compliant with specific applicability conditions. The criteria for delegation to a aircrew includes the performance capacities of both aircraft (e.g. the target aircraft profile must be compatible with the spacing instructed aircraft's flight envelope).

- The number of spacing instructed aircraft could be limited in order to permit the controller to make any needed recovery of failure.
- Application requires users to be equipped appropriately.
- Compatibility with STCA and ACAS functionality is required (for the alert and protected zones definition). Under normal conditions, the application must not trigger alarms.
- Special qualification and training for aircrew and controllers is required for this application.
- Onboard surveillance, spacing maintenance tool and display processing should be integrated with other airborne systems.
- It should be possible to transfer delegations to the next sector, i.e. without needing to cancel the delegations. Dedicated co-ordination procedures between sectors shall be defined (Requirements for co-ordination between sectors when the application spans multiple sectors is very important. In order to transmit the In-descent Spacing procedure, a service may be provided by ground to ground co-ordination, and should be integrated in the tactical control process).
- CDTI should be compatible for use of several MA-AFAS applications.

3.1.1.3.3 Associated Human factors

Airborne HMI functionalities:

- The CDTI specification must minimise any potential additional heads-down time, especially in the approach phase which is a crucial phase of flight.
- Appropriate tools/assistance shall/should be provided to the aircrew for the handling of the In-descent Spacing tasks (e.g. advisory information on how to merge at a waypoint x NM behind an aircraft, how long will it take to be at the requested spacing, alert if the spacing is outside the tolerance limit)
- If datalink is used, specific CPDLC messages for In-Descent Spacing must be implemented consistently with other Data Link clearances messages.

CWP HMI functionalities:

- Controller's display should provide information concerning all aircraft under the In-descent Spacing application. Additionally, a new task sharing will be required between planner and tactical controllers.
- Controller's display should be updated to include:
    - an indication of equipped aircraft (potential),
    - an indication for an aircraft establishing In-descent Spacing (target given),
    - an indication for aircraft maintaining In-descent Spacing (delegated).

Other human factors issues that require HMI validation include:

- Evaluate the impacts on controller mental representation of the traffic,
- Evaluate that the level of information concerning the target allows the aircrew to perform their task.
- Evaluate impacts on controller working method,
- Evaluate the workload modification for the controller and for the aircrew induced by the application, including recovery failures or exception handling.
- Acceptance and confidence by controller and aircrew.
- Define the training needed on controller and aircrew.

3.1.1.4. Operating method without In-descent Spacing

Each aircraft transitioning to descent phase is entirely managed by an APP/ACC controller. The controller gives speed and heading instructions to each aircraft in order to sequence aircraft in an approach phase.

3.1.1.5. Operating method with In-descent Spacing

Once an aircraft has transitioned to descent phase (Top of Descent has been sequenced), the application could potentially be applied. On the ground side either the APP or ACC controller may initiate spacing delegation.

3.1.1.5.1 Principles involved in In-descent Spacing

The In-descent Spacing application is based on the principle of delegation of spacing to the aircrew. Simply described, the controller indicates the desired spacing to be applied and the aircrew adjusts speed or resume his own navigation after an heading instruction, to acquire and maintain the desired spacing.

For the required spacing establishment, solution has to be provided by the controller. The aircrew is responsible to follow the controller instruction, unless they inform the controller that they are unable, as in today's operating method.

The key elements for the principle of spacing are:

- **No Obligation of use**: spacing delegation is a tool provided to the controller, and each controller has the option to use it or not.

Note: Spacing requires the agreement of the aircrew of spacing instructed aircraft. Nevertheless, since spacing is considered as a new ATC instruction, it cannot be refused by aircrew, except for reasons due to, emergency situations, or on-board failure.

- **Upon controller initiative**: a spacing instruction is always initiated by the controller, who decides to delegate if it is appropriate and helpful.
- **Limited delegation**: spacing is limited to the tasks of monitoring and implementation of a solution given by the controller
- **One parameter delegated**: in addition to limited spacing delegation, for the task that may require manoeuvring actions only one (exceptionally two) flight parameter is delegated at a time. The objective is to freeze one parameter in order to facilitate the controller mental representation of the traffic.

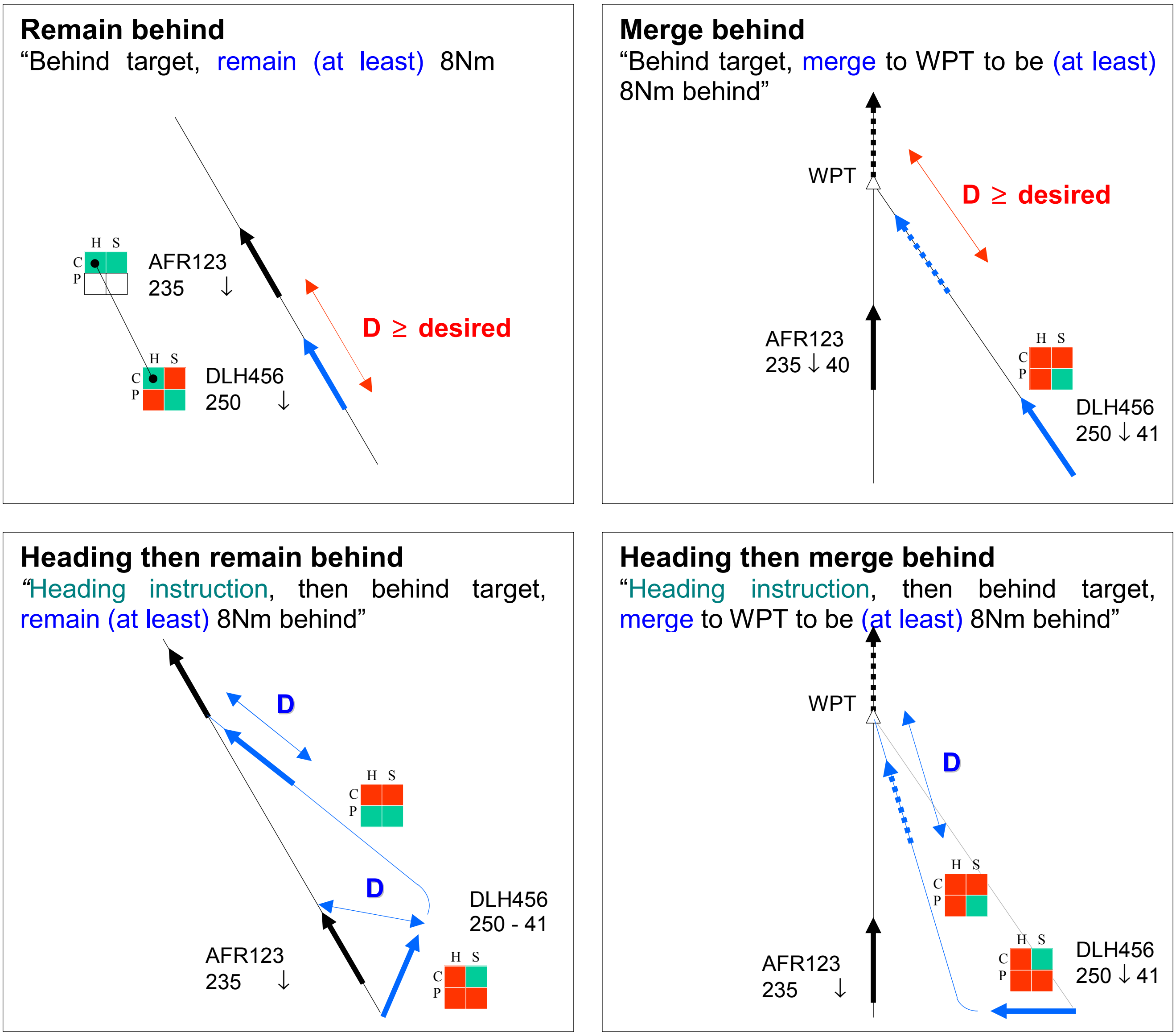
The key elements for initiating, transferring, or ending this application are:
- **Applicability conditions**: controller must ensure that all the conditions are respected before beginning an In-descent Spacing application (delegable criteria). He/she must also ensure that all the conditions remain respected during the spacing delegation.
- **Interruption of delegation**: the controller can interrupt a delegation at any time. The aircrew can interrupt a delegation in case of emergency only.
- **Transfer to next sector**: a sequence of target plus delegated aircraft may be transferred to the next sector without needing to cancel delegation.

The consequences of this application on the controller practice are the following:
- **No change of responsibility**: Delegation does not impose any change of responsibility between controllers and aircrews. Delegation can be considered as a new instruction. The controller is responsible for providing an appropriate instruction that will ensure the spacing and which is acceptable by the aircrew and compliant with the actual aircraft performance. The pilot is responsible for following this instruction.
- **Same working practices**: Spacing delegation can – and must – be used in conjunction with the current working method.

The graphic below, extracted from “CoSpace2002 simulations – Briefing Guide”, shows the four possible scenarios for delegation of spacing task. These scenarios are “Remain Behind”, “Heading then Remain Behind”, “Merge Behind”, and “Heading then Merge Behind.”

Applicability conditions

- ✔ Compatible performances
- ✔ Compatible speeds
- ✔ In-trail situations: same trajectory
- ✔ Merging situations: trajectories converging direct to the merging point
- ✔ “Remain behind” & “Merge behind”: initial separation at least equal to desired separation



Colour Convention :

Black : actual situation of target aircraft

Grey : initial situation of delegated aircraft

Dashed : predicted or potential situation

Green : controller instruction

Blue : delegated instruction

The objective of spacing instruction is to specify to the pilot the task he has to handle. This task can range from monitoring to implementation of a specified manœuvre depending on the current configuration:

- **Remain behind** : the two aircraft are flying along the same trajectory. The desired spacing is obtained, the aircrew has to maintain this spacing.
- **Heading then remain behind**: the two aircraft are flying along the same trajectory. The desired spacing is not obtained, the controller thus has to give a heading instruction. The aircrew has to follow the controller's instruction and to resume his trajectory to maintain the required spacing.
- **Merge behind**: the two aircraft are flying along merging trajectories. The desired spacing is obtained at the merging point. The aircrew has to maintain this spacing.
- **Heading then merge behind**: the two aircraft are flying along same or merging trajectories. The desired spacing at the merging point is not obtained, the controller thus has to give a heading instruction. The aircrew has to maintain the required spacing.

The delegated aircraft does not follow the target aircraft in heading changes or vectors - the delegated aircraft is vectored individually as needed by ATC.

3.1.1.5.2 List of functions involved in In-descent Spacing

The In-descent Spacing application is based on the following functions and sub-functions defined in the MA-AFAS project.

Import (surveillance) data

This function relates to the import of data from other aircraft. If the target aircraft is ADB-B equipped, the import data will be obtained through ADS-B receiver. In case the target aircraft is not ADS-B equipped, the import data can be obtained through TIS-B receiver.

Export information

This function exports data from equipped aircraft.
Information is transmitted through ADS-B or Voice (and datalink if available).
The list of data transmitted by each means is given in the section on Information Exchanges.

Display of traffic

This function provides graphical surveillance information about target to the flight crew.
It is useful for traffic identification and selection of the target aircraft. It is also useful for establishment and maintenance of required spacing.

Pilot selection entries

Pilot selections and commands are processed, for the purpose of selecting the target aircraft, for the CDTI mode selection (In-descent Spacing mode), and for inputting the spacing.

Surveillance data processing

Surveillance data processing considers target and ground surveillance data from all available airborne surveillance sources and through a data fusion process (correlating, merging,) provides computed data, such as the spacing between the two aircraft, the closure rate, and the range of error. This function also checks data accuracy and ensures data integrity.

Spacing maintaining processing

This function allows the aircrew to conduct the spacing task, including merging manoeuvres, by supporting the establishment of the required spacing and the maintaining of this spacing. This function can be defined with a wide range of automation options ranging from a manual solution, wherein the aircrew will modify its speed in order to meet the required spacing, up to the most automated option through FMS trajectory modification.

Navigation
This function is an external function that provides the In-descent Spacing application with own aircraft navigation data.

Alarming
The function provides alerts/alarms to aircrew for the purpose of maintaining spacing safely and efficiently. Examples of alerts include conditions where separation is too close or too far, and conditions where the delegated aircraft is approaching/passing the clearance termination point (if there is one). In-descent spacing alerting should be compatible with other airborne alarms (e.g. terrain avoidance, flight envelope alerting. More generally, all alerts should be compatible/conform to existing standards/prioritisation. Ground alarming function is separate but must be compatible with airborne alarming function.

3.1.1.5.3 Step by step application operational description

Identification of In-descent Spacing configuration

For any of the In-descent Spacing scenarios, the first step is that the controller identifies an opportunity to establish an In-descent Spacing application with capable aircraft. The information about aircraft equipment is displayed for each aircraft.

The controller point out an eligible aircraft and the associated target for the In-descent Spacing procedure, and propose a spacing value associated with the potential delegated aircraft.

To be eligible, aircraft must be compliant with applicability conditions (depending on manoeuvre needed: Remain or merge behind). The eligible criteria are:

- Compatible performances with target
- Compatible speed with target
- Suitably equipped aircraft
- Compatible routes (same waypoints) which may include TCP
- If an heading instruction is required, no aircraft in interference with the delegated aircraft

Prior to delegating, the controller must make sure that all applicability conditions for the envisaged spacing delegation are respected. The respect of these conditions guarantees that the delegation is safe and beneficial.

Target designation and target identification

The controller designates a target aircraft to the aircrew, using a designated identification, such as the ICAO address coded with the BICCA algorithm via voice or data link communication.

The objective is to enable the aircrew to select and visualise the target aircraft on his Cockpit Display of Traffic Information (CDTI), upon controller request.

Different ways of target identification through the HMI are the following:

- The aircrew of the delegated aircraft identifies the target on CDTI and graphically points out the target on the CDTI,
- The aircrew manually enters the target BICCA code (target ICAO address coded with the BICCA algorithm) on the MCDU or other HMI device.

- If data link is available, CPDLC provides target identification to the aircraft, such as ICAO address (coded with the BICCA algorithm). This information is directly displayed to the aircrew and confirmed.

Once the target has been selected, it appears on the CDTI. By a filtering process, it is proposed that only the target is displayed on the CDTI (for Enhanced Situation Awareness, it could also be proposed that the filtering process could be a simple selection in the displayed range). At this point, the aircrew confirms identification of the target to the controller**.**

After a target selection, if the controller decides
- To change the target, he/she has to ask the pilot to select a new target
- Not to delegate any longer, he/she has to ask the pilot to de-select the target.

Note that no agreement is required from the aircrew of the target aircraft, and no indication of becoming a target is given to the aircrew of the target aircraft. The target aircraft flies its trajectory as instructed.

In-descent spacing instruction

The controller gives instructions to perform the In-descent Spacing application. The aircrew is responsible for implementing the In-descent Spacing instruction (i.e. spacing and heading, if necessary.)

The controller gives instructions according to the current situation of the eligible aircraft.

For each option, the controller clears the aircrew to maintain a given spacing (in time or distance) either exactly or at a minimum. Maintaining a minimum spacing allows some flexibility, allowing the delegated aircrew to adjust the aircraft descent profile.

The controller must ensure that the required spacing is compatible with current traffic (i.e. including environment constraints (meteorology, complexity,…)).

For the case involving the Remain behind clearance, the controller checks that the required spacing exists.

For Heading then Merge behind situations, the controller provides appropriate instructions (i.e. heading), in order to establish the spacing.

The controller may issue a clearance limit (e.g., “until WPT”.) If the controller does not give any clearance limit, the aircrew has to contact the controller when he reaches a designated point along the final approach path (e.g., the FAF)

Aircrew’s acceptance of the In-descent Spacing instruction

The readback automatically implies the agreement of the aircrew for the forthcoming spacing delegation. If the aircrew decides – for any reason – to refuse the delegation, he/she must say so instead of the readback.

Once the controller has given instructions to perform In-descent Spacing, the spacing task is delegated on board. As it is the case with other controller instructions, the aircrew is responsible to execute the instruction in order to acquire (if specified in the instruction) and maintain the required spacing.

In-descent Spacing Implementation

The aircrew has different options for performing the task depending on the level of automation provided to the aircrew. Appropriate tools could help the aircrew to perform the task :

- Adjust his aircraft speed,
- estimation of time to resume navigation after the heading instruction.

For the "Heading then remain behind" scenario, aircrew has to : report when the aircraft reaches the desired spacing.

For the "Heading then merge behind" scenario, the aircrew has to report when the predicted spacing at the merging point would reach the desired spacing.

In order to **achieve** required spacing from the target aircraft, the aircrew could use the Flight Control Systems (autopilot or autothrottle). To maximize the maneuvre efficiency, FMS coupled with an autopilot may be helpful.

Spacing maintaining

During the maintaining of the spacing, aircrew is responsible for preserving spacing with monitoring and alerting systems and appropriate HMI.

In order to **maintain** required spacing from the target aircraft, the aircrew could use the Flight Control Systems (autopilot or autothrottle)..

The controller monitors that the delegation parameters are within the range required. In this monitoring role, the controller ensures the In-descent Spacing procedure viability (applicability conditions are still maintained).

If the controller changes his strategy, he/she could modify the delegated parameter (speed or heading)

A chain of aircraft could be handed-over from one sector to another sector. The controller must inform the other sector controller that this sequence of aircraft are under In-descent Spacing application

Termination of the In-descent Spacing

At the completion of the procedure, the spacing task is transferred back to the controller.

Different ways to terminate the application are:
- When Clearance limit is reached (WPT) or new clearance is issued
- If not specified by the controller, the aircrew has to request a controller instructions, for example, before the final approach is initiated or the FAF is reached.

Two examples of termination are:

End of delegation by the controller, where once the controller decides to end delegation, he/she issues an instruction like, "End delegation, *speed instruction*"

End of delegation by the aircrew, where once passing WPT, end delegation by the aircrew, by saying " passing WPT, maintaining *normal approach speed*."

3.1.1.5.4 Additional remarks

Implementation of CPDLC could potentially improve some application steps involving communication. Some voice communication could be easily transferred to datalink messages. As an example, the target selection by aircrew is a potential source of error (misunderstanding, wrong manipulation), unless this is mitigated through the automatic entry of target ICAO address (coded with the BICCA algorithm), coupled with aircrew verification, for safety. Additional tasks may be transferred from manual to automatic procedures by the avionics if the level of equipment capability allows for it. Nevertheless, the CPDLC induces a loss of party-line resulting in a possible decrease of the aircrew situation awareness.

3.1.1.6. Capturing Service time constraints

Surveillance will require time constraints in update rate, in order to ensure that the Required Spacing is met for this application.

Some other potential Operational Service time constraints are:
a) Expiration time
b) Anticipation time (controller identifies target plus delegated aircraft).
c) Continuity of service
d) Failure delay
e) Transition with other MA-AFAS application (e.g. Level Flight Spacing)

Figure 3 shows the Time diagram for the In-descent Spacing "**Remain behind**" scenario. Hereafter, we describe the step by step time diagram.

1) The controller identifies a pair of aircraft: detection of an In-descent Spacing eligible aircraft and the associated target. This detection could be done as soon as controller has the two aircraft on Radar in order to anticipate aircraft handling under In-descent Spacing. This task could be done by the planner in order to alleviate tactical controller workload.
2) At appropriate time, the controller gives speed clearance to the target aircraft in order to lock its speed.
3) At appropriate time, the controller indicate target's identifier to delegated aircraft.
4) Target identification: the aircrew confirms identification of the target.
5) At this time, the controller knows that delegated aircraft has identified its target. The controller says **" behind target remain XX NM behind"**
6) The aircrew evaluates the clearance feasibility, and accepts/rejects the In-descent Spacing instruction.
7) Implementation by the aircrew: once delegated aircraft has executed the delegation instruction, the aircrew says "**Remaining XX NM behind target**"
8) Now, the controller can give a new speed clearance to the target aircraft.

Figure 4 shows the Time diagram for the In-descent Spacing "**Heading then remain behind**" scenario**.** Hereafter, we describe the step by step time diagram. The steps are the same for all the scenario, except for steps 5 and 7 which are defined below.

Step 5) At this time, the controller knows that delegated A/C has identified its target. The controller gives an **Heading instruction and a distance behind target to merge**.

Step 7) Implementation by the aircrew: once delegated A/C has executed the order, the aircrew says "**Remaining XX NM behind target".**

Figure 5 shows the Time diagram for the In-descent Spacing "**Merge behind**" scenario Hereafter, we describe the step by step time diagram. The steps are the same as in the previous example, except for steps 5 and 7 which are defined below.

Step 5) At this time, the controller knows that delegated A/C has identified its target. The controller gives **a distance behind target to merge**.
Step 7) Implementation by the aircrew: once delegated A/C has executed the order, the aircrew says "**Merging distance to WPT, merging behind target".**

Figure 6 shows the Time diagram for the In-descent Spacing "**Heading then merge behind**" scenario Hereafter, we describe the step by step time diagram. The steps are the same as in the previous example, except for steps 5 and 7 which are defined below.

Step 5) At this time, the controller knows that delegated A/C has identified its target. The controller gives an **Heading instruction and a Way Point to merge**.
Step 7) Implementation by the aircrew: once delegated A/C has executed the order, the aircrew says "**Merging distance to WPT, merging behind target".**

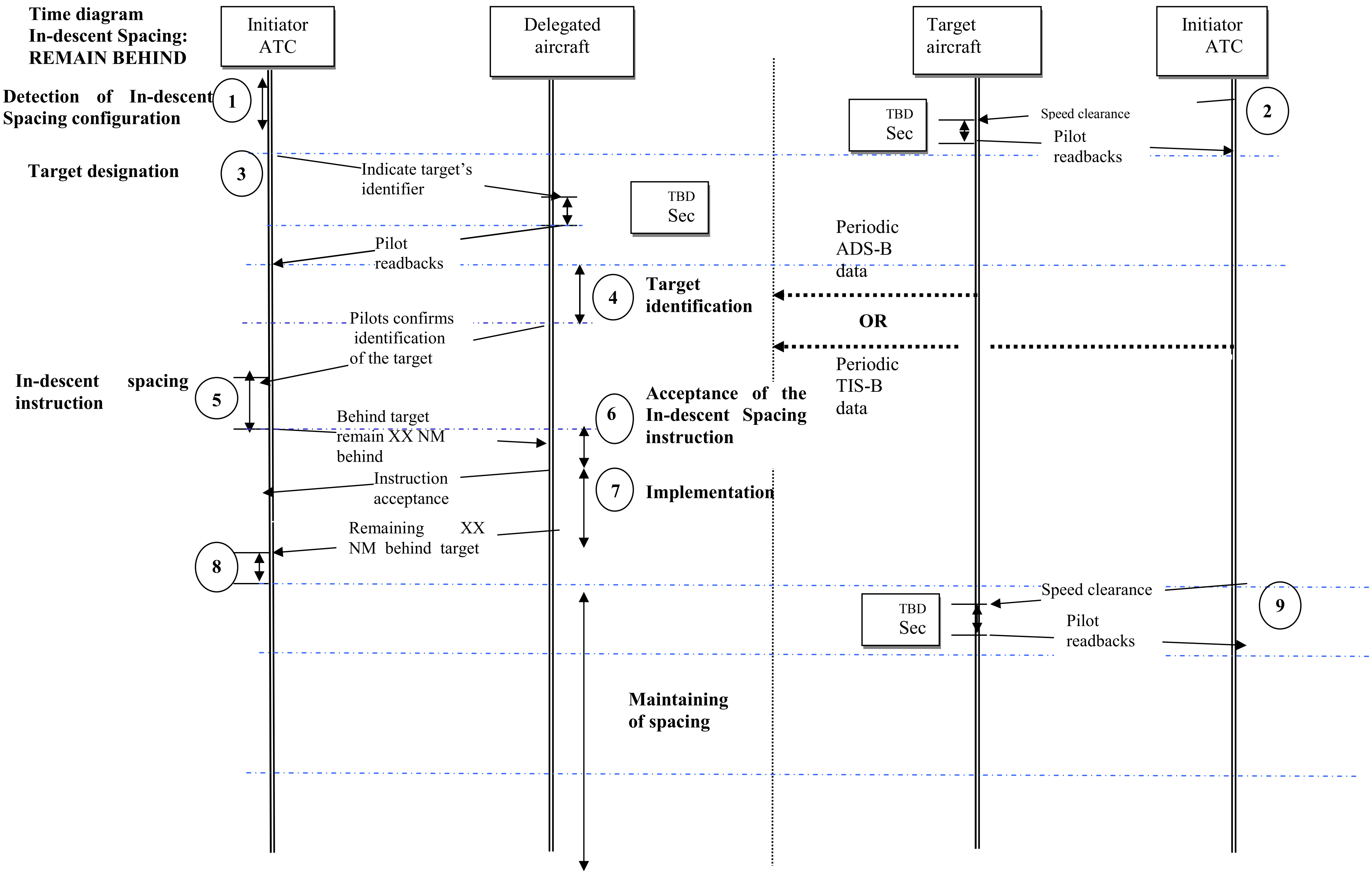


Figure 3 Time diagram: Remain behind scenario

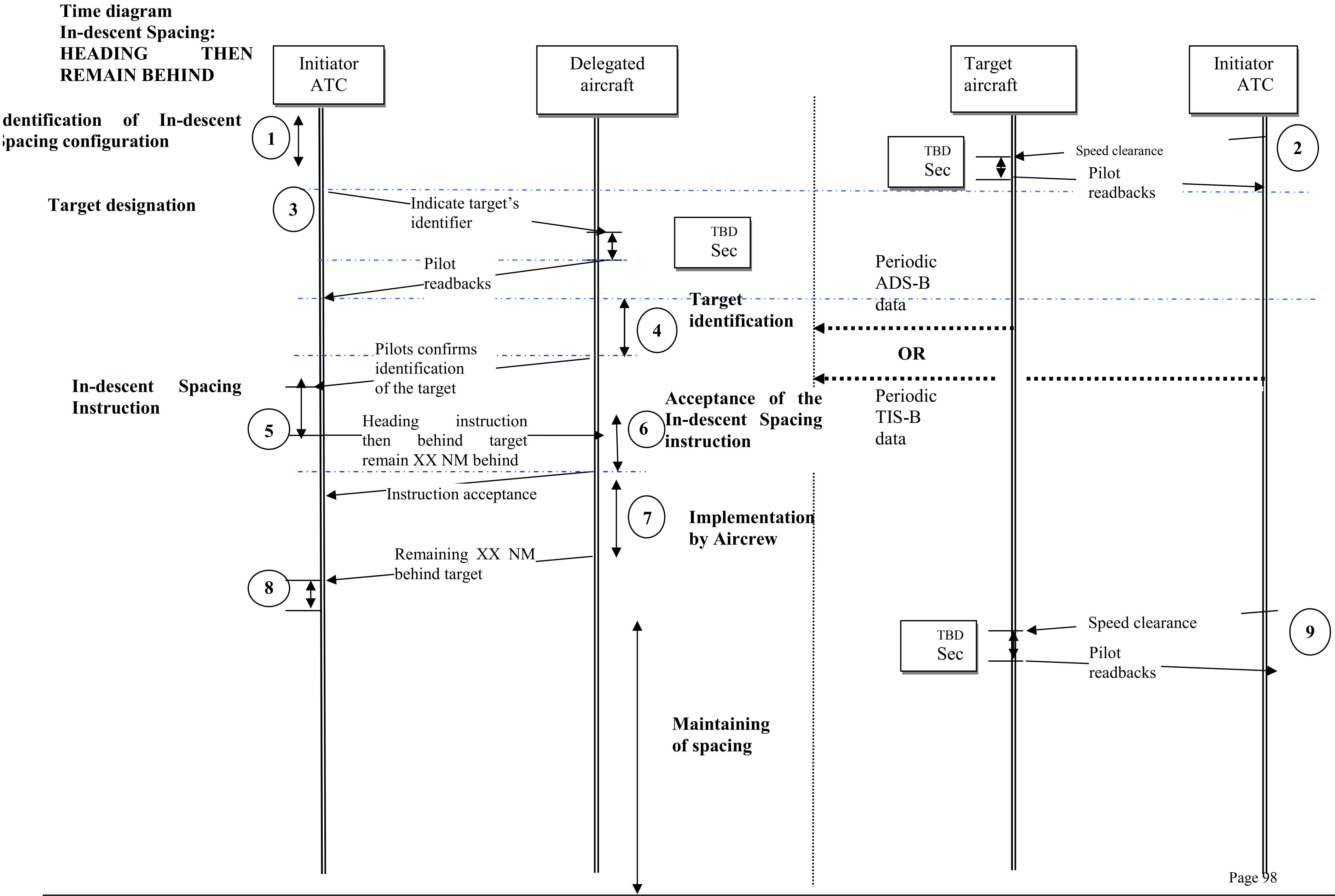


Figure 4 Time diagram: Heading then remain behind scenario

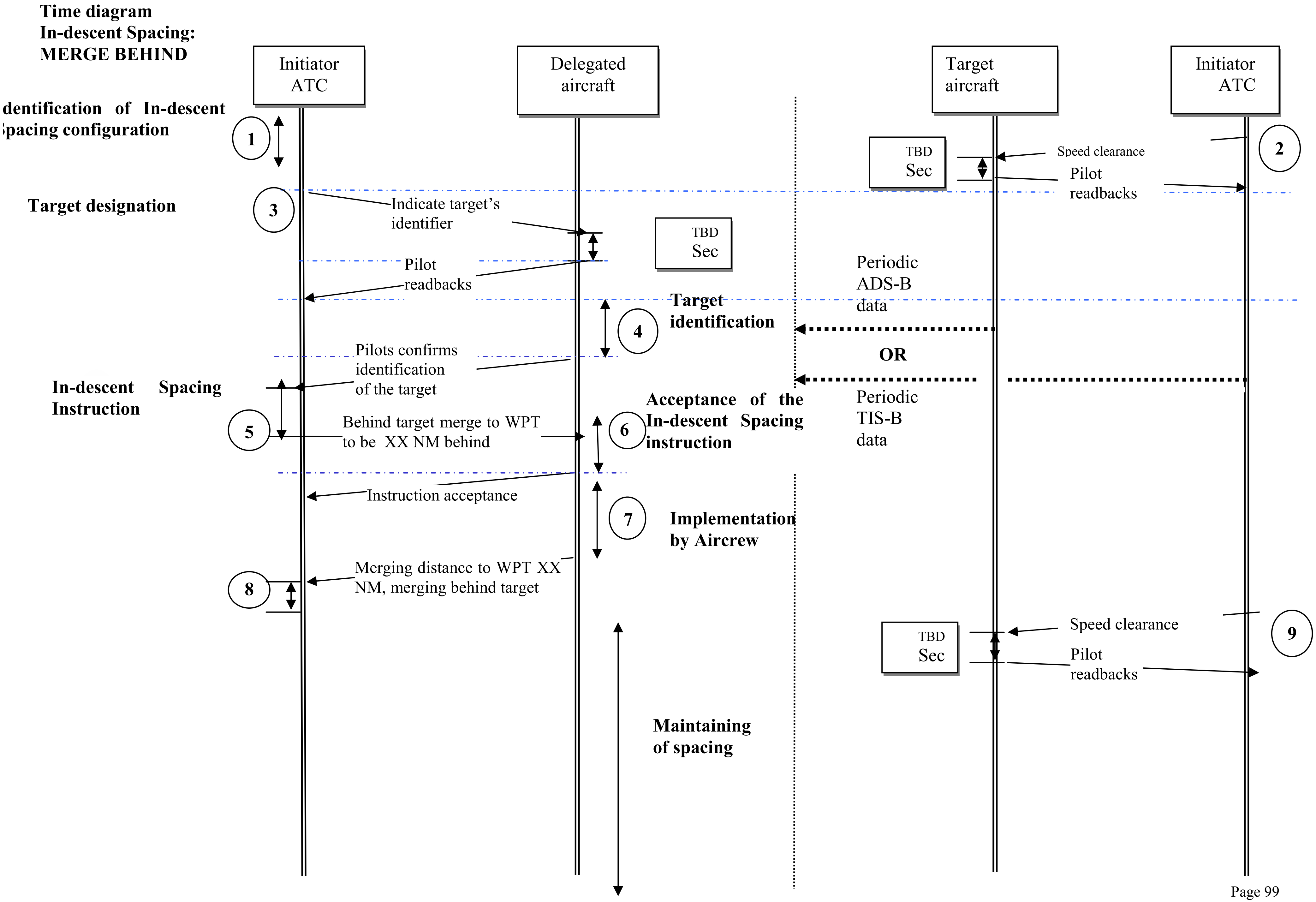


Figure 5 Time diagram: Merge behind scenario

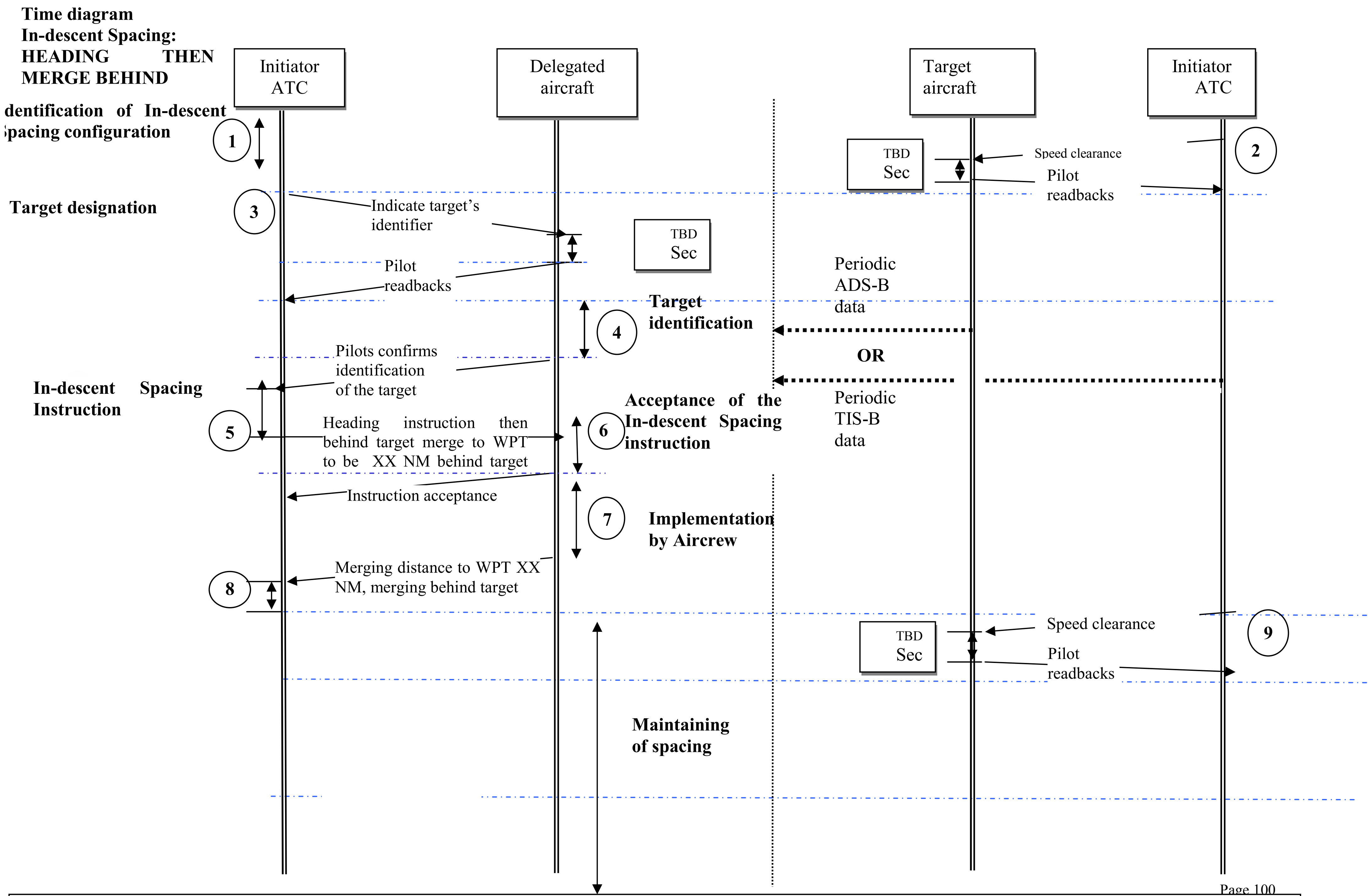


Figure 6 Time diagram: Heading then merge behind scenario

3.1.1.7. Information exchanges

3.1.1.7.1 Air/ground information exchanges
Air/ground messages are exchanged via voice or data link.
Data exchanges needed to perform In-descent Spacing application are:
- Target 24-bit ICAO address(coded with the BICCA algorithm),
- Instructions of spacing delegation.

If target is not ADS-B equipped, the ground system needs to provide surveillance information to the delegated aircraft by TIS-B. The airborne surveillance requirements for TIS-B will be detailed further in the section 4.2.

In case of voice communications, new phraseology is defined. An example of a detailed message transaction is included in section Communication services (section 4.1).

3.1.1.7.2 Air/air information exchanges

Surveillance Information about target will be provided through ADS-B if both aircraft are equipped. The airborne surveillance requirements for ADS- will be further detailed in section 4.2.

Potentially, these data could be correlated with ACAS data to ensure a higher level of integrity. Note that ACAS must remain the safety net in case of problems.

3.1.1.7.3 Avionics information exchanges

Information will be exchanged with other avionics systems (for example, primary flight display, and Navigation Display). Examples of data to be exchanged include:
- CDTI selection mode
- closure rate
- navigation data.

At a minimum, an ASAS system should monitor the quality of the data used to form target aircraft tracks and should also monitor the integrity of position data in ADS-B reports.

3.1.1.8. Exception handling

This application will be used in conjunction with the current ATC working method. The delegation is considered a new type of ATC instruction and dedicated exception handling procedures must be defined.

In case of failure in In-descent Spacing, a procedure takes place as described below in this two-level process (depending on the emergency):
- Fall back procedures (no imminent danger): after modifications in the delegation parameters, the controller could continue the application or re-initiate a new In-descent Spacing application with new delegation parameters,
- Escape procedures: the priority is to restore safety by cancelling the application and going back to spacing task allocation to ground.

If an exception handling procedure is initiated, all exchanges between the controller and the aircrew should be conducted over voice communication (VHF).

Each exception handling procedure is differentiated by the exception detection and the induced action. Detection can be conducted either by the aircrew or the controller, but all action can only be initiated by the controller, except in case of vital emergency.

Exception handling detection	By controller or by aircrew	By ACAS
Action triggered by	Controller clearance	RA (aircrew has to follow RA)

3.1.1.8.1 Fallback procedures

As a basic principle, any problem must be reported to the controller within a time which permits the controller to perform a fallback procedure. After that, the controller has to provide a solution to the aircrew. If the controller does not provide a solution in an appropriate time (TBD), he/she has to apply an escape procedure.

The controller has to start a fallback procedure if the delegated aircrew notifies the controller that they are unable to maintain the In-descent Spacing application (for any reason).

The controller has the choice either to restore the ground-based procedure or to re-initiate an In-descent Spacing application, depending on the look ahead time.

In the Radar monitoring task, the controller may detect a violation in Radar based separation To restore the normal mode, the controller may give Heading instructions in order to restore the separation. The detection of conflict is made by Radar detection, thus this monitoring and separation assurance tasks are not different than today.

If the target aircraft has a technical problem and is not able to follow its assigned clearance, the application will be terminated. The spacing task transfers back to the controller and the aircraft will be sequenced by ground based procedures.

3.1.1.8.2 Escape procedures

In case of emergency, the priority is to restore safety by cancelling the application and going back to ground based sequencing procedures.

By restoring ground based sequencing procedures, effective and safe application of sequencing will be performed by the controller (including use of redundant systems and capabilities). A Ground based ATM environment will replace all the ASAS tools in case of aircraft sequencing difficulties and escape procedures will take place.

Any broad equipment failure impacting on the application viability will terminate the application.

Escape procedures must take into account the compatibility with ACAS. Spacing applied in In-descent Spacing application should not overlap the ACAS protected zone. When ACAS generated an RA, application should be terminated. The aircrew has to follow the RA generated by ACAS.

3.1.2 Level Flight Spacing

3.1.2.1. Operations service description

Level Flight Spacing application consists of a new procedure initiated by the controller and accepted by the pilot, which requests an aircraft in level flight on a track to maintain a longitudinal spacing behind another one in level flight too. The aircraft can be steady at different flight levels. The application only addresses longitudinal Spacing and includes the merging phase when aircraft can be on converging tracks. However, it does not address Spacing with lateral offsets (i.e. aircraft flying on parallel tracks).

Level Flight Spacing is mainly focused on aircraft in **cruise flight**. However, the application can also be applied between aircraft in level flight during a regulation phase in **Approach**.

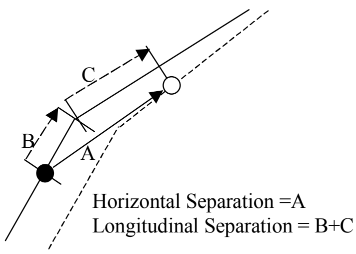
For cruising aircraft, **level flight changes** are part of the application although an aircraft is not steady during a period of time. Indeed, the altitude change is limited (usually less than 2,000 ft) and the vertical speed during this manoeuvre is low.

Level Flight Spacing will be applied on a **time or distance spacing objective**. Some simulations in Approach (e.g. cockpit simulations performed by SAS within the framework of NUP Arlanda Tiger Team), in particular in case of speed variations, have highlighted that time spacing is more efficient and requires a lower pilot workload than distance spacing. However, for steady aircraft, the speed variations are low and both types of spacing objectives can be applied, depending on the controller strategy and constraints.

The controller can set up **a chain of aircraft** by providing a Level Flight Spacing instruction to a third aircraft relatively to the second one. This latter one will be at the same time a delegated and target aircraft.

Level Flight Spacing is a **new procedural instruction** from an ATC point of view. The responsibility for separation assurance task remains with the controller. He provides the appropriate clearance and when the spacing is established, the pilots have to maintain it. This is similar to a vertical clearance for instance. The controller clears an aircraft to FL280 and another one to FL290. When both aircraft are steady at their cleared flight level, they have to maintain their assigned altitude and the controller is not responsible to continuously monitor that they are doing so. On the other hand, Level Flight Spacing is a new type of procedure for the aircraft and the aircrew. It implies that navigation is directly dependent on another aircraft and it is not only performed according to flight plans and standard ATC clearances.

Level Flight Spacing is performed **along the target aircraft trajectory**. It means that in the case of a Trajectory Change Point (TCP), the long track distance (B+C) or time will be assured in respect to the spacing objective of the clearance but the range between the aircraft will momentarily decrease. However, this distance (A) must remain greater than the ground separation minima.



In order to maintain spacing while in a chain, it may be necessary for the delegated aircraft to be able to vary the spacing objective from the target aircraft within some limited **margins**. The delegated aircraft is allowed to operate within a volume of airspace. Indeed, it may be detrimental to the delegated aircraft if it is required to throttle forwards and backwards, in order to maintain a very fixed spacing. For instance, automatic pilots oscillate around the cleared flight level when steady, with low altitude deviations and low vertical rates.

3.1.2.2. Scope and objective

The application can be implemented in En-route and Approach radar Managed Airspace.

Three levels of equipment can be distinguished:

- aircraft with the appropriate equipment to perform the Level Flight Spacing application, including at least a CDTI and ADS-B/TIS-B capabilities, and possibly new navigation functions and CPDLC;
- aircraft with ADS-B capability to perform a Level Flight Spacing procedure through a surveillance based on a direct air-air datalink;
- aircraft with current level of equipment.

The first type of aircraft can either be target or delegated aircraft. The second one can only be target aircraft like the third one but this latter one requires a TIS-B infrastructure to provide surveillance data to the delegated aircraft.

The main objective of the application is to increase the airspace capacity through a reduction of the controller workload by the process of a chain of aircraft instead of several single aircraft.

3.1.2.3. Expected benefits, Anticipated constraints

Expected benefits

An expected reduction of the controller workload together with an increased pilot traffic situational awareness could lead to a possible increase of sector capacity. Indeed it can be anticipated that to process a pair of aircraft (or even a chain of several aircraft) should consume less effort than to process each aircraft individually. For instance, if the controller reduces the speed of the target aircraft, the delegated one will automatically reduce its speed (supposing that it is feasible) without any additional ATC clearance

The presentation of the traffic on a CDTI to the pilots should increase their traffic situational awareness if a relevant traffic filtering is implemented to avoid cluttering.

Level Flight Spacing and In-Descent Spacing can be applied sequentially if the delegated aircraft has the correct capabilities to also perform In-Descent Spacing. For instance, if two aircraft with the same arrival airport are on the same route during the cruise flight, the en-route controller can initiate a Level Flight Spacing procedure, that will be later automatically modified to an In-Descent Spacing instruction when the delegated aircraft is cleared for Top of Descent.

Nevertheless the controller is still responsible for the Top of Descent of the delegated and target aircraft. Similarly, if during the descent the aircraft level off at an intermediate flight level based on controller clearances, the application will be automatically modified to a Level Flight Spacing while they are steady and the In-Descent Spacing will restart automatically when the first aircraft starts to descend again after a new controller clearance. Temporary Level Flight Spacing during In-Descent Spacing should be transparent to the controller.

Some cases may imply the need for a new clearance, this can occur anywhere during the application and is dependent on the controller assessment :

- When the spacing value has to be modified,

- When the spacing criteria has to be changed (distance to time),
- When the clearance limitation is reached or has to be modified.

If it is not sufficiently equipped to perform In-Descent Spacing, the delegated aircraft will cancel the delegation when reaching the TOD.

Anticipated constraints

The evaluation of the controller workload has to take into account the establishment of the Level Flight Spacing procedure. If it requires too much effort, the overall controller workload will not be reduced significantly enough to allow an increase of airspace capacity.

The hand-over procedures between sectors should be modified in order to address the hand-over of pairs of aircraft instead of single aircraft. If a Level Flight Spacing procedure is only valid within one sector, the foreseen advantages might be significantly decreased.

The procedure for transition between Level Flight Spacing and In-Descent Spacing should be simple to keep the associated benefits. In particular, during the descent phase, if the two aircraft have to remain steady to comply with some controller clearances, the temporarily use of Level Flight Spacing during the In-Descent Spacing should be transparent for the controller.

The benefits will have a significant impact on the airspace capacity if the Level Flight Spacing procedure is often applied. However, in the transition period some limiting factors may impact negatively the optimisation of the application:

- the partial equipage of the fleet with the appropriate equipment for Level Flight Spacing is a limiting factor since the Level Flight Spacing procedure will not be able to be applied as often as wished by controllers.
- the partial ADS-B equipage will also limit the number of Level Flight Spacing procedures. Nevertheless, it could be mitigated thanks to the implementation of a ground infrastructure providing TIS-B.
- controllers might not manually detect all the configurations enabling the initiation of a Level Flight Spacing procedure. The development of a tool for the controller to identify such configurations would enable a greater number of Level Flight Spacing procedures.

The expected reduction of the controller workload shall not significantly increase the pilot workload. Assistance through new airborne functions and maybe automation would probably have to be implemented to help the pilot during the Level Flight Spacing procedure.

Based on current situation, the increase of airspace capacity thanks to Level Flight Spacing will be a shared benefit for all the airspace users and not only for the airlines that would have paid to equip their aircraft. Solutions should be found to provide direct benefits to airlines that fit suitably their fleet to speed up the equipment of all aircraft.

3.1.2.4. Human factors

On the ground side, controllers should be aware through the ground system of aircraft capabilities to be able to identify which aircraft can perform a Level Flight Spacing instruction. Once a Level Flight Spacing instruction provided, the pair of aircraft should be easily identifiable by on the controller working position. A more complex system could also include a tool that would provide suggestions to controllers by identifying pairs of aircraft for which Level Flight Spacing instruction could be provided.

The controller surveillance means, i.e. SSR, should not be modified to support this application.

On the airborne side, a CDTI is necessary for the pilot to identify the aircraft with which he is proposed to perform a Level Flight Spacing instruction. In particular, the traffic identification provided by the controller should be easily interpretable and quickly correlated with the information provided on the CDTI. This display will also be used during the monitoring task.

The CDTI features should be identical for both Level Flight Spacing and In-Descent Spacing to ensure a smooth transition between them. They may require specific functions compared with other applications. For instance, it may be useful for the monitoring task to display to the pilot a vector indicating a relative displacement of the target. As aircraft should have similar speeds, i.e. no closure/distancing rate, the display of an arrow would indicate the necessity to undertake a corrective manoeuvre.

New airborne functions should be implemented to assist the pilot during the Level Flight Spacing procedure. In particular, the equipment should enable him to determine whether the Level Flight Spacing instruction provided by the controller is achievable, to establish the required spacing, to maintain it and to alert him if the spacing objective is no more achieved. The pilot has to be kept informed on the status of all these functions. Nevertheless, during a Level Flight Spacing application, the target aircraft should not modify continuously its speed, contrary to an In-Descent Spacing even if some low speed variations can happen. Consequently, it can be envisaged in a first step to perform a Level Flight Spacing application without any automation if the clearance does not last too long (the maximum duration being to be assessed).

3.1.2.5. Operation without operation application

When two aircraft in cruise flight are on a same track during the cruise flight, the controller provides spacing thanks to speed (mach) clearances. This strategy is only applied for types of aircraft with similar performances. In other cases, other solutions are applied (e.g. different flight levels for overtake). Nevertheless, sequencing with speed clearances can also be provided to aircraft at different flight levels in order to regulate the traffic, for instance for hand-over constraints.

The controller usually asks the first aircraft its speed and checks with the second aircraft whether it can maintain this speed. If it can, it is cleared to do so. If it cannot, the controller can check with the first aircraft whether it could slightly modify its mach (e.g. from point 74 to point 76). Once a common speed accepted by both pilots, the controller monitors the speed changes until the cleared speed is maintained by both aircraft. If it is not possible to find a common speed, the controller applies a vertical solution to prevent the aircraft to converge at the same flight level.

The spacing applied between aircraft is usually much greater than the separation minimum. It is not always optimised to be as close as possible to the desired value for hand-over procedures.

To apply a specific time spacing target for the purpose of hand-over to the next sector, the controller estimates the corresponding distance with the actual speeds and then adjusts the speed of the second aircraft to get this appropriate spacing. First he decelerates (or sometimes accelerates) it and then provides a clearance with the same speed than the target aircraft with the adequate anticipation time to take into account the deceleration phase.

If the controller wishes to modify the target aircraft speed once the spacing is established or if the target aircraft requests to modify its speed, the controller has to co-ordinate with the delegated aircraft for a new speed before the provision of new speed clearances to both aircraft.

During hand-over, every aircraft is transferred individually, requiring a co-ordination between the different sectors for each of them.

Level Flight Spacing can also be applied between aircraft in level flight during a regulation phase in Approach. The description of operations for cruising aircraft applies with the following main differences:

- the speed clearances are provided in Indicated Air Speed (IAS) and not in mach values;
- the distance between the aircraft may be lower, i.e. closer to the separation minima;
- the aircraft will remain steady a few minutes whereas in cruise flight, it can be expected to have Level Flight Spacing during several tens of minutes.

3.1.2.6. Operation with operation application

The procedure for two aircraft is composed of the following list of actions.

It can be extended to a second pair of aircraft. In this case, the delegated aircraft of the first pair will become the target one of the second pair. However, the provision of a second Level Flight Spacing instruction involving the delegated aircraft of a pair of aircraft cannot be provided before the pilot reports the establishment of the first one.

Step 1: Identification of Level Flight Spacing configuration

The controller identifies two aircraft in a configuration that enables the initiation of a Level Flight Spacing procedure. To be eligible, the pair of aircraft must be compliant with applicability conditions. The eligible criteria are :

- Compatible performances
- Compatible speeds
- Suitably equipped aircraft
- Compatible routes (same waypoints) which may include TCP

They are steady and follow or will soon follow the same route. They may be at the same flight level or not (regulation between two aircraft with the same destination but with different cruise flight levels). If aircraft are complying with these cases of eligibility, the delegated aircraft shall receive information about the target aircraft, such as the position and speeds. It means that either the target one has the capability to broadcast this data through ADS-B or an additional surveillance means (TIS-B) is available.

Step 2: Level Flight Spacing instruction to delegated aircraft

The controller asks the aircrew of the delegated aircraft with the appropriate communication means (i.e. VHF or CPDLC if available) whether he can perform a Level Flight Spacing clearance which includes 4 parameters:

- **the target aircraft identification**: As the callsign of an aircraft cannot be provided to another aircraft by VHF because of a risk of misinterpretation of the clearance by both aircrews and as the SSR code is not unique and is not provided by ADS-B, a new identification mean shall be used. The ICAO 24-bit address will be used coded with the BICCA algorithm.
- **the time/distance spacing objective and the margins**. The controller determines what parameter is the most relevant according to the present situation. (*Note: It can be envisaged that these margins could be asymmetrical (e.g. 10 NM, +1.0 NM and –0.5 NM) and that they could also be defined by default (e.g. +10% and –5%)*)
- **the starting point**. This is the point from which the spacing has to be established, i.e. the aircraft are on the same track and separated by the time/distance
- **the clearance limit** (e.g. duration, waypoint). It has to be located within the current sector, for instance the exit point. This clearance limit is necessary because in case of a loss of communication the pilot knows until when he has to apply the Level Flight

Spacing procedure. This is an extension of the current procedure that is for a pilot to follow his flight plan in case of communication loss.

Step 3: Aircrew's acceptance of the Level Flight Spacing instruction

The aircrew identifies the other aircraft on the appropriate equipment (CDTI and possibly selecting device) and checks whether the Level Flight Spacing instruction proposed by the controller is feasible, taking into account both speeds, the time/distance spacing objective or the possible merging manoeuvre. Then the pilot confirms whether he accepts the instruction or not.

Step 4: Controller's acknowledgement

The controller acknowledges the acceptance of the instructionby the aircrew of the delegated aircraft.

If the pilot refuses the Level Flight Spacing instruction, the controller can check with the pilot of the target aircraft whether he can slightly modify his speed to achieve a Level Flight Spacing instruction. If an agreement cannot be found, the controller will apply current solutions.

Step 5: Aircrew capture of the Level Flight Spacing value of spacing

If the aircraft are on the same track, the aircrew controls the aircraft speed to reach the assigned time/distance spacing through the appropriate system. It can be either a manual or semi-manual operation (throttle, auto-pilot and CDTI) or an automatic manoeuvre if new navigation functions are available (relative navigation). This spacing implementation is similar to the one for the "Remain behind" of the In-Descent Spacing.

If the aircraft are not on the same track, the pilot of the delegated aircraft first continues on the current heading until reaching the target aircraft track, then he turns to achieve the same track and then proceeds like in the first case.

Step 6: Reporting of the Level Flight Spacing establishment

If a dedicated guidance system is used for the capture, it informs the aircrew when the spacing objective is established, who reports the information to the controller.

If the capture is performed manually or semi-manually by the aircrew, he will determine on the CDTI when the spacing objective is established and report to the controller.

Step 7: Monitoring and maintaining of the Level Flight Spacing value of spacing

As the aircraft should have fixed and identical speeds during Level Flight Spacing, the aircrew of the delegated aircraft will have mainly a task of monitoring that the spacing objective is correctly performed within the defined tolerance. This monitoring can be done thanks to a CDTI but if the Level Flight Spacing procedure has a long duration, the aircrew cannot keep on looking continuously at the display. An alerting system would have to inform him when the spacing objective is no more achieved. It could be envisaged to inform the aircrew before the spacing objective is no more achieved.

If the target aircraft modifies its speed (e.g. temporary slowdown because of big clouds or ATC clearance), the delegated aircraft will have to automatically adjust its speed. If there is an available advanced guidance function to perform the Level Flight Spacing, it will detect the speed change and will modify the delegated aircraft's one in consequence. A status message will inform the pilot about this automatic action. If the Level Flight Spacing is performed by the aircrew, the pilot will manually adapt his speed to maintain the spacing objective within the margins.

The controller does not have any specific monitoring task between both aircraft, as today once he has noticed on his screen that the cleared speeds are applied and that the spacing is appropriate. Nevertheless he remains responsible for separation assurance and he has to include both aircraft in his situational awareness like all the other ones.

Step 8: Hand-over to the next sector

To hand-over a pair of aircraft in Level Flight Spacing procedure, the controller (C1) calls the controller of the next sector (C2) to transfer the target aircraft as today. C1 adds that there is a delegated aircraft in Level Flight Spacing with the time/distance spacing objective. C2 accepts the transfer of the pair of aircraft and extends the Level Flight Spacing instruction to the entry point of his sector.

C1 calls the target aircraft for transfer like today. A bit later C1 calls the delegated aircraft for transfer. He first instructs it to continue the Level Flight Spacing to the entry point of the next sector. After the pilot’s readback, he adds the frequency of the next sector.

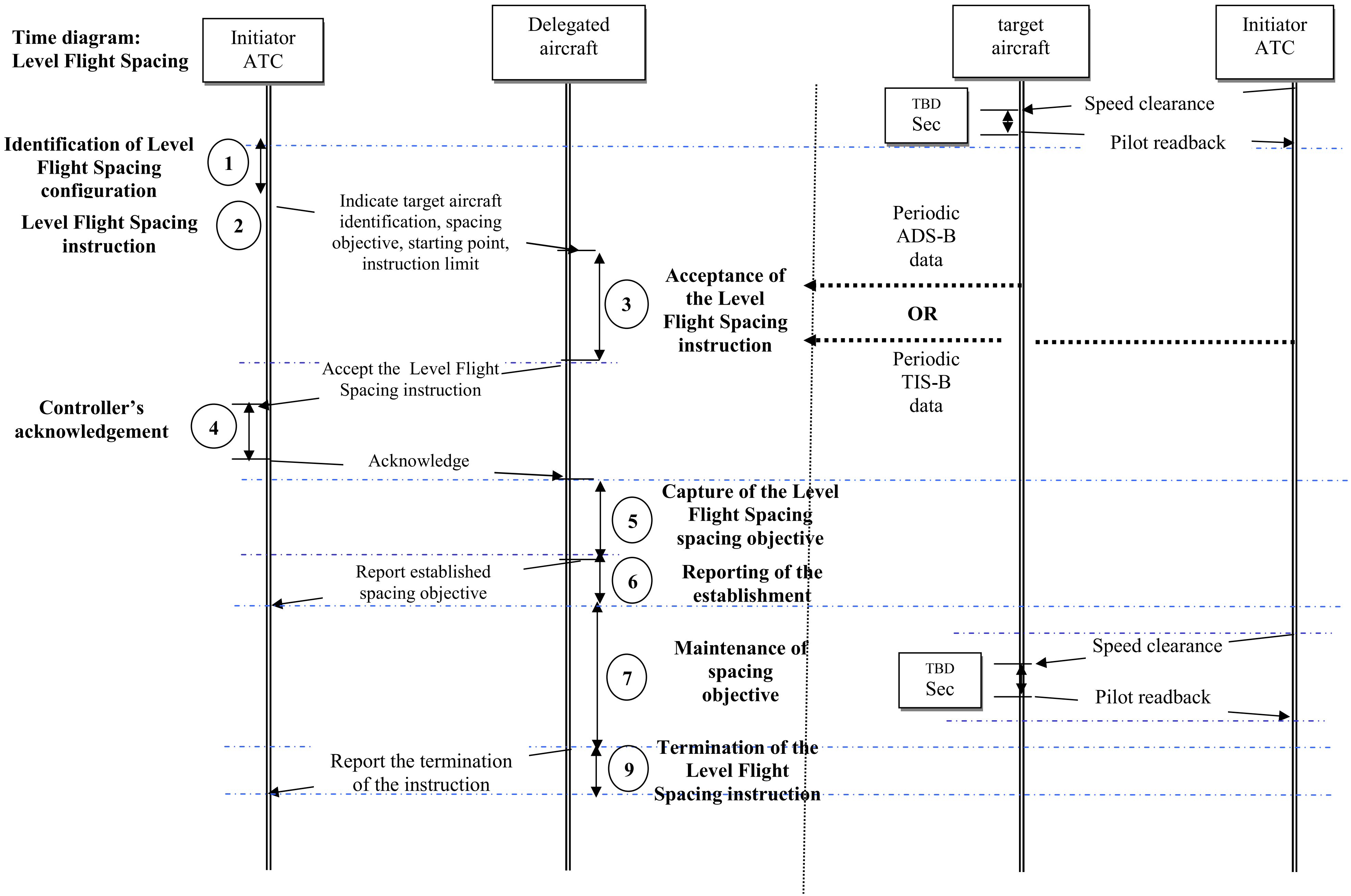
When the delegated aircraft contacts C2, this latter one can extend the Level Flight Spacing instruction to the exit point of his sector.

This hand-over procedure is similar to the current one: there is the same number of exchanges between pilots and controllers and the co-ordination between sectors involves several aircraft at any time as it is sometimes the case currently in case of Letter of Agreement.

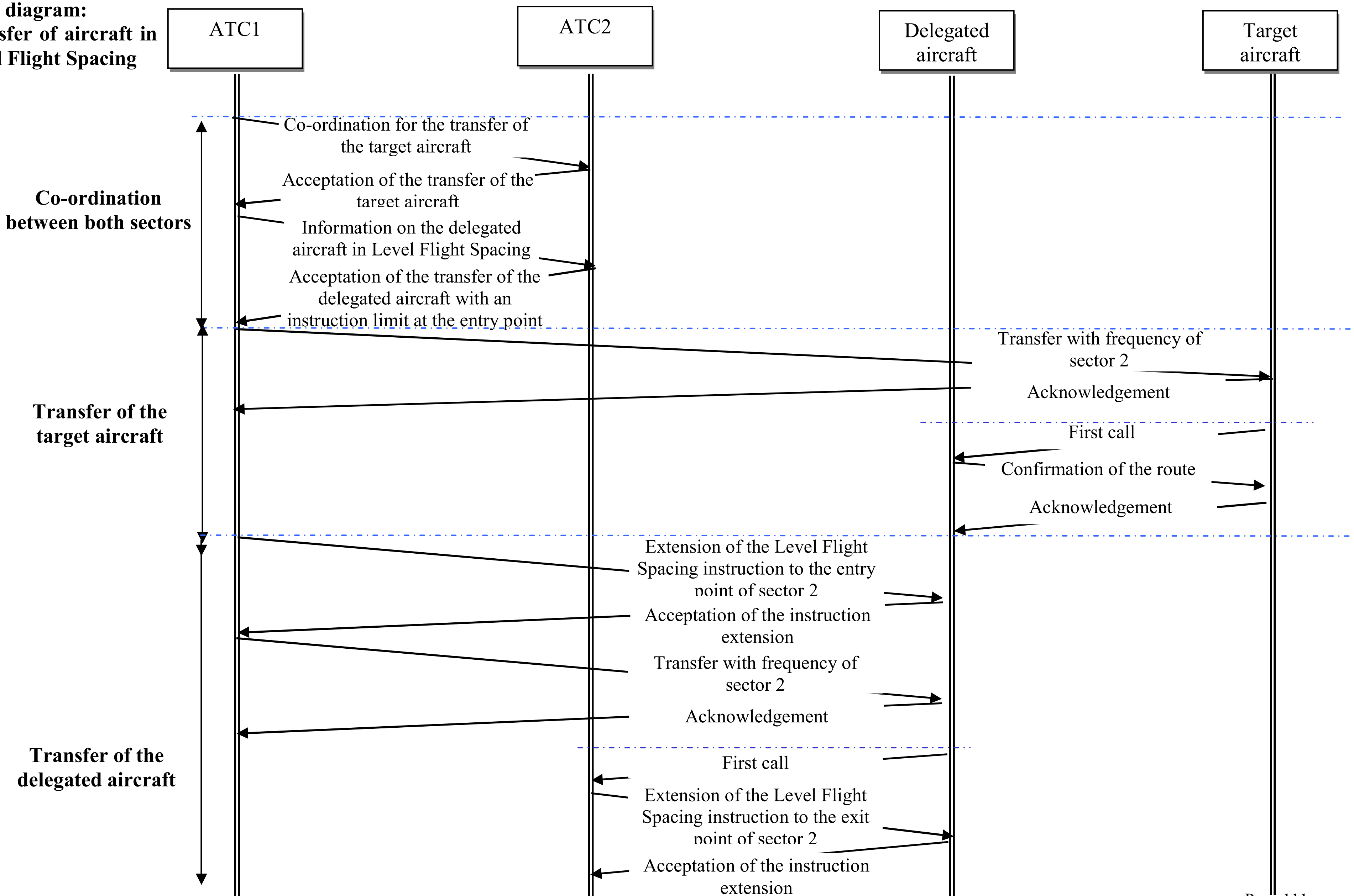
Step 9: Termination of the Level Flight Spacing instruction

In normal operations, the procedure ends at the instruction limit specified by the controller. The pilot informs the controller that the Level Flight Spacing is finished and that he resumes his navigation according to his flight plan.

Non-standard terminations are described in chapter “Exception handling”.


Time diagram:
Level Flight Spacing
Initiator ATC
Delegated aircraft
target aircraft
Initiator ATC
TBD Sec
Speed clearance
Pilot readback
Identification of Level Flight Spacing configuration
1
Level Flight Spacing instruction
2
Indicate target aircraft identification, spacing objective, starting point, instruction limit
Periodic ADS-B data
Acceptance of the Level Flight Spacing instruction
3
OR
Periodic TIS-B data
Accept the Level Flight Spacing instruction
Controller's acknowledgement
4
Acknowledge
Capture of the Level Flight Spacing spacing objective
5
Report established spacing objective
Reporting of the establishment
6
Maintenance of spacing objective
7
Speed clearance
TBD Sec
Pilot readback
Report the termination of the instruction
Termination of the Level Flight Spacing instruction
9

Time diagram:
Transfer of aircraft in Level Flight Spacing



3.1.2.7. Application time constraints

For communications, there is no specific time constraints since the application is mainly designed to be used with VHF.

The airborne surveillance is the most critical component in particular because it is based on two different means: ADS-B and TIS-B. In particular, the update rate, the accuracy, the availability, the latency and the integrity of both means should be consistent and enable to perform Level Flight Spacing procedures relatively to an ADS-B or non ADS-B aircraft. If the airborne surveillance performances based on ADS-B and on TIS-B are not similar, the level of equipment of the target aircraft could have an impact on the spacing objective. Therefore, the ground system should be aware of the aircraft level of equipment to determine what values of spacing objectives and of margins are feasible.

3.1.2.8. Information exchanges

Air/ground communication is primarily based on VHF. New phraseology has to be defined for the provision of the Level Flight Spacing instruction by the controller as well as the associated acceptance and the establishment report by the aircrew. The messages for anticipated termination (e.g. new ATC clearance, TCAS manoeuvres, etc.) will be identical to the current ones.

The provision and establishment of the Level Flight Spacing instruction could be performed thanks to CPDLC if the delegated aircraft is suited for. This could be achieve by the use of “Free Text” or by the definition of a new ACL message. In this case, it could even be envisaged to automatically present to the pilot which aircraft he is requested to follow.

No air/air point-to-point communication is necessary for this application.

The surveillance on-board the delegated aircraft will be performed by either ADS-B or TIS-B. Consequently, the requested information to provide to the aircrew has to be included in both ADS-B and TIS-B messages.

The basic set of requested data is:

- ICAO 24-bit address;
- position (latitude, longitude, altitude);
- velocity vector (ground speed, track angle, altitude rate).

Additional data may contribute to improve the procedure efficiency:

- callsign;
- NUC_P and NUC_R;
- TCPs.

As the airborne surveillance data may come from two different sources (i.e. ADS-B and TIS-B), the required surveillance performances should be consistent in terms of update rate, accuracy, availability, latency and integrity. In case of discrepancy, the lowest performance will dimension the system.

The ground surveillance does not require any change from the current one. It is still based on SSR information and Radar Data Processing System (RDPS).

3.1.2.9. Exception handling

In normal operations, the procedure ends at the clearance limit specified by the controller at the initialisation. Nevertheless it will end at specific cases. All the exchanges between the controller and the pilots during non-standard terminations have to use the VHF channel.

If the aircrew of the delegated aircraft detects the inability in maintaining the required time/distance spacing taking into account the tolerance, he will report it to ATC. The controller will then provide new clearances to the aircraft (e.g. a speed clearance).

If the controller detects a surrounding conflicting aircraft and that he wishes to change the trajectory of one of the aircraft involved in the Level Flight Spacing procedure, he will interrupt the Level Flight Spacing procedure and he will provide new instructions to solve the conflict.

If a change of the controller strategy occurs, he will interrupt the Level Flight Spacing procedure and he will provide new instructions to match with the new strategy.

If a failure of an equipment required for the application (e.g. ADS-B transceiver, CDTI, etc.) occurs, the pilot of the delegated aircraft will inform the controller who will provide new instructions.

If the target aircraft is ADS-B equipped and that the delegated aircraft receives from it some TCPs different than its, the pilot will inform the controller that he interrupts the Level Flight Spacing procedure. This case should be exceptional because if aircraft have different flight plans, the controller should not plan Level Flight Spacing procedure between them.

If an emergency status occurs on-board one of the aircraft, the pilot of the involved aircraft will inform the controller who will provide new instructions to both aircraft.

ACAS is not part of the application and shall remain as an independent last resort backup. It can be anticipated that the interaction between ACAS and the Level Flight Spacing application should be limited. Indeed, ACAS algorithms are based on a time-to-collision and during a Level Flight Spacing procedure (and even during the merging phase) the aircraft have similar speeds. Consequently, the time-to-collision should be high since the relative speed is very low. In addition, the longitudinal separation applied currently between aircraft is very large in terms of collision avoidance. Therefore it could be anticipated that ACAS should not trigger any unnecessary Resolution Advisories if Level Flight Spacing is performed according to the procedure definition.

When ACAS generates an RA, pilots always have to comply with their airline operational instructions, which are usually to follow the RA. If a pilot deviates from his trajectory to follow an RA, the Level Flight Spacing procedure stops automatically. Pilots have to inform the controller about the RA as soon as possible. By following RAs, pilots become responsible for their collision avoidance. The controller is no more responsible for the provision of separation for the deviating aircraft. and he has the responsibility to provide traffic information as appropriate. Pilots will report to the controller the “Clear of Conflict” generated by ACAS. The controller will then provide new clearances (which could be either current procedures or a Level Flight Spacing one).

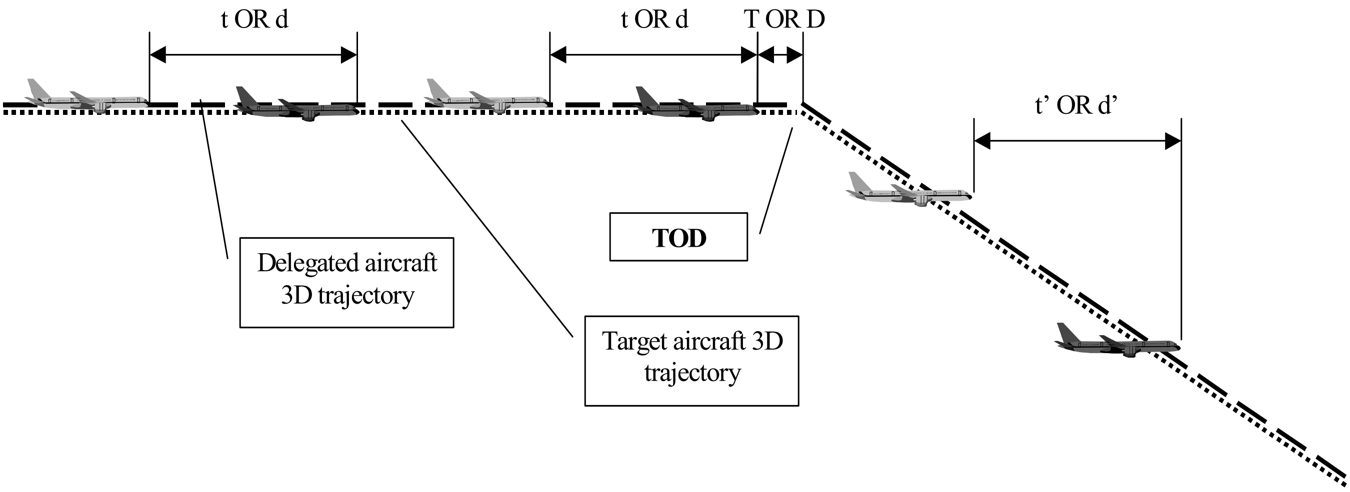
3.1.2.10 Scenarios for Level Flight and In-descent Spacing

The differentiation between Level Flight Spacing (LFS) and In-descent Spacing (IDS) is a procedural one made by ATC alone. Onboard the delegated aircraft, there is no requirement for treating the two cases differently, though the actual control laws being applied may be different according to whether the aircraft is climbing, level, or descending and are also dependent on the speed and type of aircraft and the spacing type selected by the controller: time or distance.
Clearance messages are the same for Level Flight Spacing and In-Descent Spacing : a clearance is interpreted as an LFS or IDS clearance by the delegated aircraft, depending on its current phase of flight.

If the delegated aircraft receives a Top Of Descent clearance while performing LFS, this imply an automatic transition to IDS.

When an aircraft is performing LFS or IDS, the controller can change the required spacing by issuing a further REMAIN BEHIND TARGET or MERGE BEHIND TARGET instruction. This includes the case where a delegated aircraft in LFS retains the same spacing as it changes to IDS on receipt of a TOD clearance; if the controller wishes to change the spacing, s/he has to do this explicitly by providing a new instruction.

1. Instructed for Level Flight Spacing then controller clears Top Of Descent :

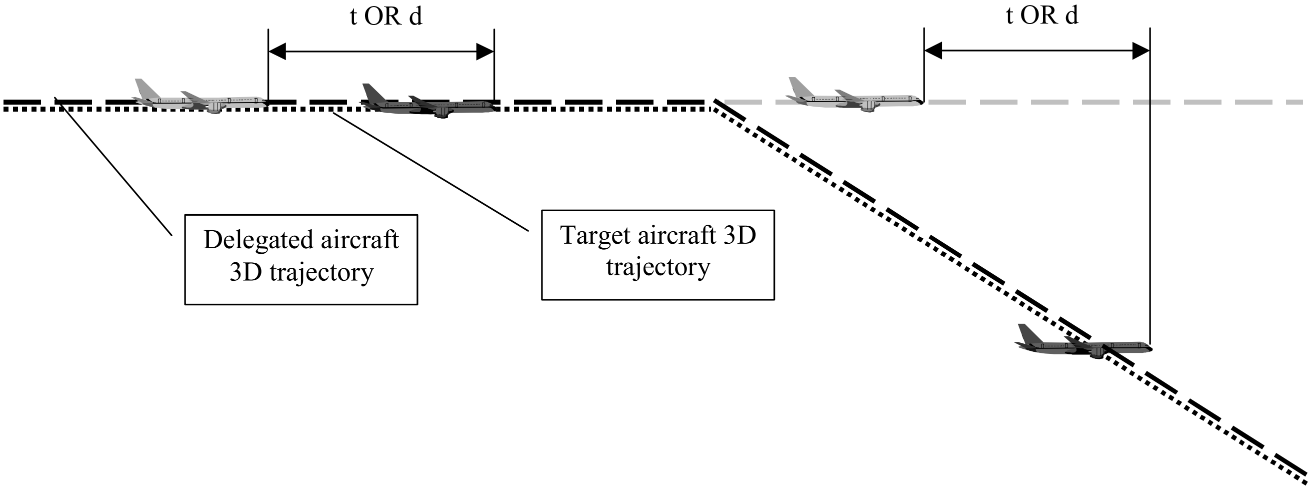


- t OR d is the instructed spacing in Level Flight Spacing.
- t’ OR d’ is the instructed spacing in In-Descent Spacing. This is the same as LFS spacing unless the controller gives another spacing instruction at or after TOD.
- T OR D is the normal minimum distance or time from the target aircraft to TOD before delivery of Top Of Descent clearance to the delegated aircraft.

This is the normal LFS to IDS scenario.

Note that the delegated aircraft continues to fly its own trajectory, possibly modified by ATC tactical commands. It does not follow the target aircraft’s lateral or vertical profile..
An aircraft performing LFS that is capable of IDS will automatically begin IDS on receipt of TOD clearance. An aircraft that is not capable of IDS will signal CANCELLING DELEGATION when it receives TOD clearance

2. Instructed for Level Flight Spacing, but controller doesn't clear TOD for delegated aircraft:

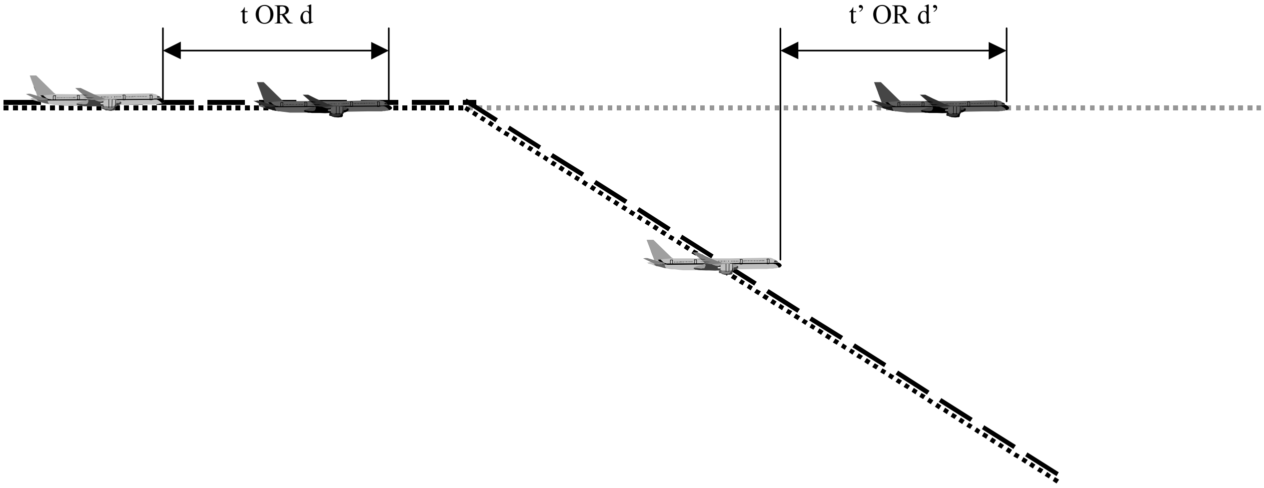


This is an abnormal scenario for illustration purposes only, showing that the vertical profile of the delegated aircraft is independent of the target aircraft.

The delegated aircraft does not descend if Top Of Descent clearance is not given (could be strategic or tactical) but maintains LFS while the situation is resolved. Resolution is either automatic when the delegated aircraft detects a vertical rate of the target aircraft greater than 200 ft/min* and unilaterally cancels the LFS (pilot informs ATC verbally), or by the delegated pilot noting an anomaly during his routine monitoring of the target and querying the situation with ATC.

* Note that this rate has been set so that cruise vertical manoeuvring rates in level flight do not trigger the cancellation but the higher vertical rates after TOD will trigger it.

3. Instructed for Level Flight Spacing then controller clears TOD but target doesn't descend:



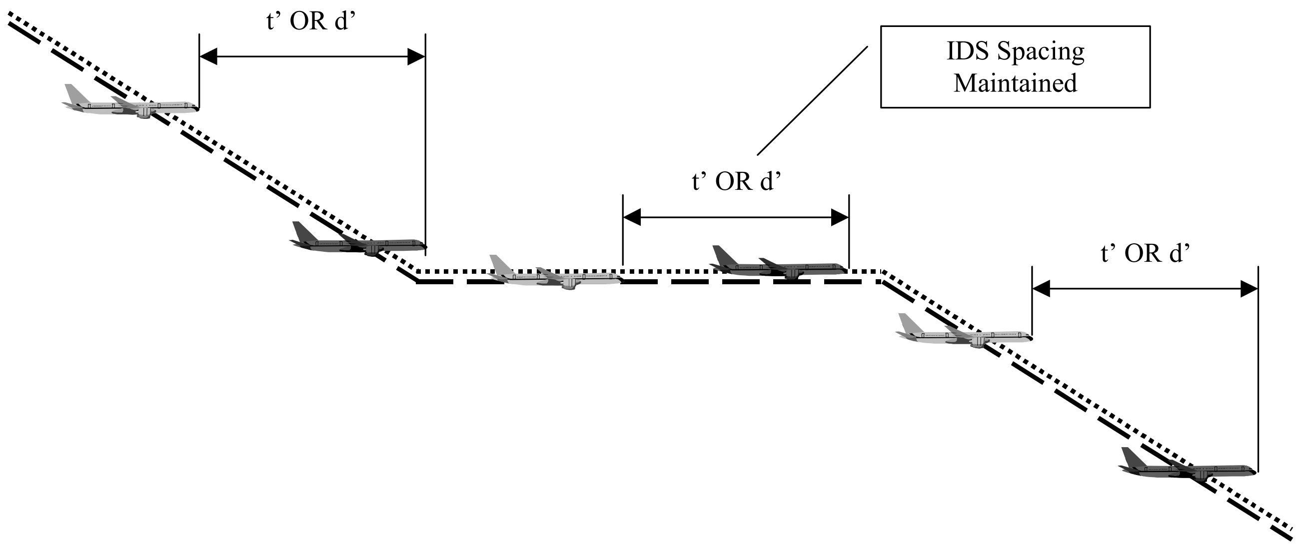
This is an abnormal scenario for illustration purposes only, showing that the vertical profile of the delegated aircraft is independent of the target aircraft.

The delegated aircraft is given TOD clearance.

The target aircraft does not descend if Top Of Descent clearance is not given or if it has a problem but the delegated aircraft maintains IDS while the pilot verbally queries the situation with ATC (expect IDS to be cancelled).
Note that there is no alert generated in this condition, as the delegated aircraft has received TOD clearance and suspended its <200ft/min monitoring of the target aircraft. This abnormal condition is

expected to be noted primarily by the controller who still has authority over the manoeuvre, with the pilot also expected to monitor the target aircraft during the manoeuvre and able to note an unexpected situation, and lastly the FMS continues to monitor that the aircraft is manoeuvring within its preferred envelope – if this condition is not met the pilot and ATC are alerted and the manoeuvre is cancelled

4. Instructed for In-descent Spacing then ATC clears both aircraft to level out and then continue descent:

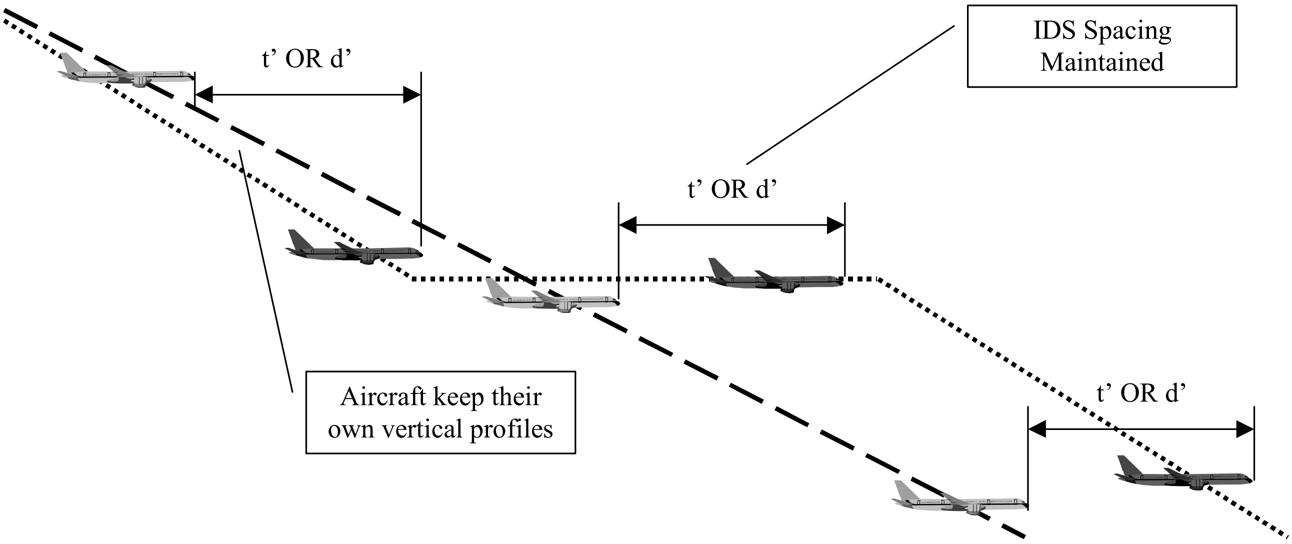


This is a normal scenario where ATC requests both aircraft to level out temporarily.

The delegated aircraft maintains its instructed IDS spacing during the level phase and during the following descent.

Note that there is no difference in the delegated aircraft's operations, though the level phase of its flight is described as "Temporary LFS".

5. Instructed for In-descent Spacing then target levels out without delegated aircraft being given clearance to level out:



This is a normal scenario where ATC requests only the target aircraft to level out (for instance if the two aircraft have different preferred descent profiles) showing that the two aircraft have independent vertical profiles.
The target aircraft is cleared to level out temporarily but the delegated aircraft is not, so it maintains its vertical profile whilst also maintaining the IDS spacing (if it's possible).
Note that there is no difference in the operation of the delegated aircraft and the procedure is described as In-descent Spacing throughout.

Summary of both Spacing procedures types:

ID	Feature	Level Flight Spacing	In Descent Spacing	Comments
1.	time spacing	YES	YES (preferred)	specified with instrcution
2.	distance spacing	YES	YES (not preferred)	specified with instruction
3.	automatic transition for flight not under spacing procedure	NO	NO	requires explicit ATC instruction
4.	automatic transition out of flight under spacing procedure	NO	NO	requires explicit ATC instruction
5.	automatic transition to other spacing procedure	YES (to IDS)	YES (to LFS)	this is an ATC procedure name change only as there is no change to the instruction and no effect on the aircraft
6.	target and ownship 2D trajectory identical	YES	YES	prerequisite for entry to Spacing procedure mode
7.	lateral offset capability	NO	NO	both aircraft must have the same lateral path (tolerance 2 x RNP)
8.	delegated and target vertical profiles independent	YES	YES	each follows its own cleared vertical profile (strategic OR tactical) irrespective of what the other aircraft does

3.1.3 Lateral Applications/Crossing and Passing

New allocation of spacing tasks between controller and flight crew has been envisaged as one possible option to improve air traffic management. The objective is to identify a more effective task distribution beneficial to all parties. This allocation of spacing tasks to flight crew is expected to increase controller availability and to improve safety, which in turn could enable better efficiency and/or, depending on airspace constraints, more capacity.

3.1.3.1. Operations Service Description

This application is intended to allow one aircraft to cross another aircraft or pass another aircraft on a similar track in airspace regions (e.g. oceanic or non-radar equipped managed airspace) where the standard separation criteria would not normally permit such a manoeuvre. However, the lateral crossing application can also be considered for feasible standard sectors. The general idea is to transfer the task of maintaining spacing between two aircraft from the ground to the airborne side, similar to the in descent spacing and level flight spacing applications when feasible, in terms of safety and efficiency.

This application will assess the operational aspects dealing with ATC delegation tasks of crossing/passing manoeuvres operations in the TMA area, Climbs and Descents, En-route, Oceanic and non-radar areas. (Autonomous operations are not addressed in this context)

Requirements for this transfer of task include the provision of a Cockpit Display of Traffic Information (CDTI) for the flight crew and the broadcasting of aircraft state data and, if available, intent data from the surrounding air traffic in order to provide the necessary airborne situational awareness to the crew. The system on-board could have planning aid/guidance.

The application is reliant on this provision of surveillance information to the flight crew via the CDTI.

In situations where the ATC controller determines that a change in route (lateral aspects) is preferred, a Clearance is sent to the aircrew (the current air/ground communications would be adequate to satisfy this application). If execution of the manoeuvre can be conducted safely with another aircraft on a similar track, the controller can delegate the spacing task to the flight crew. This entails the crew using the CDTI to confirm that the spacing distance and the relative closure rate to the other aircraft are within set tolerances to ensure that the spacing distance will be maintained throughout the manoeuvre. These values are also defined to prevent the flight crew from having to continuously monitor the spacing condition throughout the cross/pass manoeuvre. A periodic monitoring of the situation should be sufficient. These lateral crossing manoeuvres should be behind the other aircraft.

HMI symbols should be provided to the pilot showing when the crossing manoeuvre is active – crossing mode. The crossing mode is activated by the clearance from controller or acceptance from pilot, and deactivated by the pilot by the "crossing completed/failed" message sent to the controller. The controller can terminate the crossing application at any time and recover the spacing task.

In order to ensure the crew of the other aircraft is kept aware that an aircraft will be crossing/passing in their vicinity, the controller should notify the aircraft subject for crossing (could be flight crew task in the future). This allows them to advise the other crew of their intentions and to confirm that the other aircraft will not be making any lateral or vertical changes to its own flight path during the crossing procedure. On completion of the cross/pass manoeuvre, the flight crew will advise ATC. ATC will inform the other aircraft. The spacing task is restored to the ATC controller.

During a delegation, the pilot will be in charge of establishing and/or maintaining the spacing, by modifying the heading for passing and/or traffic merging. The pilot must determine when the crossing is completed. To assist the pilot in this task, a cockpit display of traffic information (CDTI) with the necessary indications will be provided.

It's most likely that an ATM tool will be designed or modified to cater for monitoring spacing, rate of closure etc. between aircraft subject for different applications based on delegation of spacing.

To conduct this application the following elements are required on board:
- Crossing/passing (i.e. delegated) aircraft must be ADS-B equipped or able to receive both ADS-B and TIS-B information in order to be able to collect information on the surrounding traffic and the target aircraft (not required to be ADS-B equipped).
- A new or retrofit display (CDTI) is required onboard delegated aircraft to allow the identification of the target aircraft as well as to allow the monitoring task.
- Data Link communications are not required but desirable as a second communication link.
- Requirements for pilot/controller communications include new phraseology for the application for voice or datalink.
- Training

The following elements are required on the ground:
- TIS-B is required in case of mixed traffic
- In order to insure consistency between controller view and aircrew view, CWP, Controller Working Position must include display of ADS-B information.
- Requirements for pilot/controller communications include new phraseology for the application for voice or datalink.
- Requirements for controller decision making.
- New operational working procedures
- A new task has to be made by the controllers having impacts on controller workload and on controllers task sharing between planner and tactical controller.
- Training

3.1.3.2. Scope and Objective
The overall objective of this application is to enhance the capacity available within this airspace, through the identification of a more effective task distribution. More specific the purpose of this application is to allow aircraft to change their heading/track to improve their flight efficiency (less effort and maximum accuracy) or to avoid adverse weather by using delegation of spacing task. The procedure (lateral crossing) should enable direct operational improvements in airspace regions under procedural control, which are beyond the normal surveillance coverage from the ground and/or have limited communications. The controller workload will decrease due to delegation of the spacing task. The opportunity to define a common goal and to have a common representation of the surrounding world is believed to facilitate communication issues and act preventive for mishaps. These objectives are derived from the description of function AS-27, Crossing application (lateral passing and crossing), from the MA-AFAS WP1.3 Functional Decomposition document.

Aircraft need to be equipped with a CDTI and to be able to receive broadcast aircraft state information either via Automatic Dependent Surveillance - Broadcast (ADS-B) or Traffic Information Service – Broadcast (TIS-B) (ground-derived). Air/ground voice communications do not require any modifications from the current equipment, although in unmanaged airspace a channel may need to be allocated to allow air/air voice communications. This latter item would permit the crew of the other aircraft to be advised of the intended manoeuvre and therefore to improve their situational awareness.

3.1.3.3. Expected Benefits and Anticipated Constraints

Expected Benefits

The benefits expected from this procedure are the following :

On the ground side :
- More efficient flight path (i.e. shortened way to fly). Less effort timewise for the air transport system (aircrew / ATC)
- The responsibility of maintaining spacing is transferred to the pilot so the controller workload is reduced i.e. the spacing task is temporarily delegated
- More direct actions / adjustments is believed to be the result if actions are initiated on data available for the AirCrew i.e. less slack from detection to action;
- Increased integrity of data

On the airborne side :
- Increased accuracy when executing a crossing manoeuver
- Increased Situational awareness

Cumbersome shift in cruise altitude for oceanic or non radar airspace could be avoided by using the lateral crossing application.

The benefits include greater flexibility and efficiency for flight operations in regions of limited ground surveillance and/or communications. Similarly, the controller's workload for handling an individual flight would be reduced due to the delegation of spacing tasks to the flight crew, resulting in less communication and monitoring activities for the controller. This reduction in controller workload per flight can also allow an increase in the effective airspace capacity. An additional benefit is the greater opportunity to avoid adverse weather conditions and therefore provide as comfortable a flight as possible for the passengers.

Anticipated Constraints

Anticipated constraints include the requirement for sufficient number of aircraft to be suitably equipped for broadcasting aircraft state and possibly intent information. Unless there is involvement of a relatively high proportion of the aircraft in this airspace, there will not be the necessary data available for the CDTI to provide the required situational awareness to the flight crew to perform the monitoring task. On the other hand one equipped aircraft could execute crossing manoeuvres on other aircraft subject for TIS-B. This means that a specific benefit for that particular aircraft could be identified. The airborne situation is likely to incorporate a mix in the level of equipment fit on the aircraft and this will determine whether the controller will be able to delegate spacing tasks to the flight crew. The information on an aircraft's equipment fit needs to be available to the controller, possibly via the flight plan. This application also requires the data to be transmitted with the accuracy and update rate sufficient for the flight crew to safely perform the surveillance role. Finally, the flight crew have the right to not accept the delegation of spacing task due to heavy workload.

- a need for appropriate tools in the cockpit and on the ground to support the application;
- a need for compromise between performance characteristics of different aircraft;
- a need for adequate airspace for establishing and disestablishing,
- a need for sufficiently long stretches of straight and level airspace to be maintained in order to accrue benefits.

Benefit would have to be achieved in the form of reduced delays and/or fuel savings which have environmental effects. The 'maintain spacing' phase would have to be of sufficient duration to off-set significant what appear to be disbenefits in establishing and disestablishing the chain, and in handing over between sectors. The benefits achieved in the 'maintain spacing' phase would have to be sufficient, for both airlines and ATC, to off-set the cost of necessary support tools and training.

3.1.3.4. Human Factors

A CDTI needs to be situated in a position where the flight crew can easily view the display. This display should provide graphical representation of the location of surrounding aircraft relative to the own aircraft. The information on the display should include the call sign, altitude and track of each aircraft within range.

This display should have an adjustable range control. It should also provide the capability to select one of the surrounding aircraft and to display additional information relating to this aircraft's spacing and the relative closure rate with the own aircraft. A level band with range +/- 5000ft should be included to enable task focus according to the minimum information principle. This should be sufficient for the flight crew to perform the monitoring task during the crossing/passing manoeuvre.

For this application, the communication between the flight crew and the ATC controller can be either via voice or CPDLC. In the case of CPDLC, there must be some form of data link screen in the cockpit, which allows the crew to format the cross/pass request message and transmit this to ATC or vice versa. Similarly, any ATC response will be shown on the CPDLC display. The current library of CDPLC messages will need to be extended to include lateral cross/pass requests and clearances.

Human factors issues that need to be addressed include:

- the suitability of position information alone to support separation assurance;
- the feasibility of designing effective alternative cockpit tools;
- whether the application can only be implemented as an FMS mode or function of the autopilot.
- interaction style and communication with ATC
- trust and confidence must be investigated and measured from both sides
- disturbances on ATC function and it's impact on airborne side
- disturbances on airborne side and it's impact on ATC
- Phraseology and communication issues must be designed to avoid ambiguity i.e. the BICCA code (ICAO address converted to readable format). The representation on ATM and Airborne side of a flight must to a maximum extent be unambiguous and direct

3.1.3.5. Operating Method without Operation Application

It's believed that a user friendly application crossing would generate mutual benefits in traditional ACC sectors. The method of issuing a vector vs give instructions for an unambiguous crossing must be considered. Currently the ATCO is using his "radar eye" in order to judge if a vector must be issued to avoid traffic. The ATCO could also use the prediction line (PRL) which point to an anticipated future position of the aircraft with current speed / heading. The PRL is normally limited to maximum 1- XX minutes but other values may exist. PRL is often used as an on / off function because of cluttering effect. Currently, aircraft operating in oceanic or non-radar equipped airspace are required to be separated by large distances due to the lack of independent surveillance means. Under these conditions, it is necessary for pilots to radio their positions to the ATC controller at defined intervals or points along the route in order to provide the controller with some form of surveillance information. The level of navigation performance and air/ground communications that are available in these regions, are additional factors affecting the required spacing values. This type of airspace normally implements a fixed or flexible route structure. Lateral separation of routes is of the order of 100 nautical miles with aircraft operating at the same altitude and the same track required to be at least 10 minutes apart longitudinally (this can equate to up to 120 nautical miles for typical cruise speeds). Above FL290, aircraft are separated vertically by 2000 feet, but with the introduction of Reduced Vertical Separation Minima, this is being reduced to 1000 feet in certain areas.

To optimise an aircraft's fuel consumption or to avoid the effects of adverse weather, flight crews may request to ATC for a change in cruise altitude. Currently, due to the large separation distances that must be maintained, ATC may not be able to clear the manoeuvre because of the proximity of other traffic on a similar track but at a different flight level.

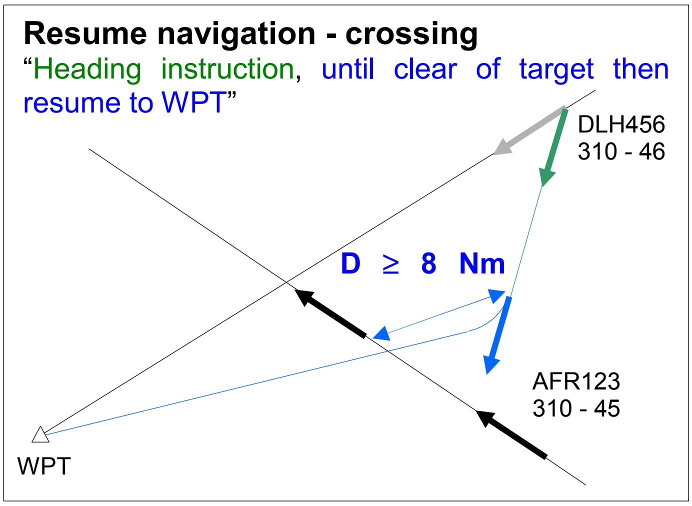
3.1.3.6. Operating Method with Operation Application

3.1.3.6.1 Crossing Manoeuvre

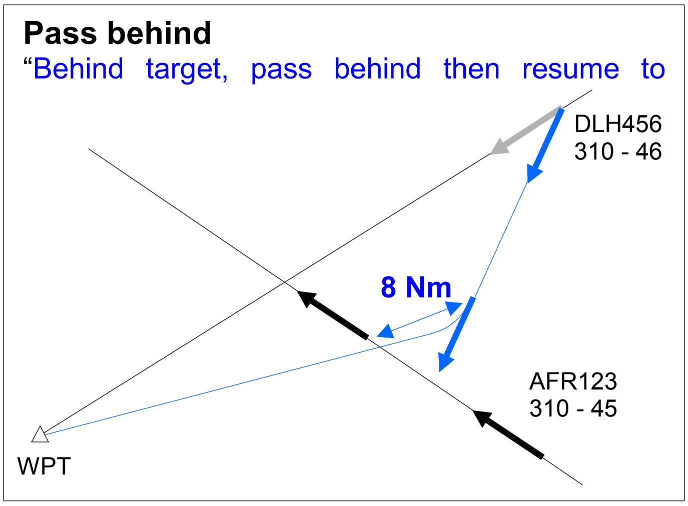
Crossing manoeuvre is always to be performed Behind the selected A/C. The spacing has to be maintain by the pilot and should be greater than the separation minima.

The delegation of the crossing could be of two levels.
On the first level the controller indicates the initial heading to use (XX-YY degrees) to commence the crossing manoeuvre. The pilot follows the heading instruction, until s/he considers it safe to resume track.
On the second level the pilot decides both initial heading and when to resume.
See figures below – (Spacing Distance X=8NM)

First Level



Second Level:



Colour Convention :

Black : actual situation of target aircraft

Grey : initial situation of delegated aircraft

Dashed : predicted or potential situation

Green : controller instruction

Blue : delegated instruction

3.1.3.6.2 Crossing Phraseology

Resume navigation-Crossing (First Level)**: heading** … **until clear of target** then resume to WPT
- *Identification phase*
- Controller: "DLH456, *heading instruction* until clear of target, then resume to WPT"
- Pilot: "*Heading instruction readback* until clear of target, then will resume to WPT, DLH456"
- Controller: "AFR123, maintain heading (for spacing)"
  Then, once clear of target:
- Pilot: "DLH456, clear of target, resuming to WPT"
- Controller: "AFR123, normal nav"

Pass Behind (Second Level): **pass behind** then resume to WPT
- *Identification phase*
- Controller: "DLH456, behind target, (to the left) pass behind, then resume to WPT"
- Pilot: "(To the left) passing behind target, then will resume to WPT, DLH456"
- Controller: "AFR123, maintain heading (for spacing)"
  Then, once clear of target:
- Pilot: "DLH456, clear of target, resuming to WPT"
- Controller: "AFR123, normal nav"

The target A/C identification is based on the unique BICCA code (24 bit ICAO code processed by the BICCA-algorithm).

This new identification should be viewable on the monitors for the controllers and on the CDTI for the pilots. The id should be shown on request and/or when needed for a certain application mode. The pilot could have a way to enter the id code, and the system should highlight the selected A/C on the CDTI. When datalink is available, the system will highlight the selected A/C automatically.

3.1.3.6.3 Passing Manoeuvre

Passing manoeuvre to the right or to the left of the selected A/C. The spacing has to be maintain by the pilot and should be greater than the separation minima.
On the first level, the controller indicates the initial offset to be used to commence the passing manoeuvre. An additional climb instruction can be given (not mandatory). The pilot follows the offset instruction (and climb if it has been cleared), until s/he considers it safe to resume track.

On the second level the pilot decides both initial offset and when to resume.
An additional climb instruction can be given also (see paragraph 3.1.3.6.4)
See figures below. – (Spacing Distance X=8NM)

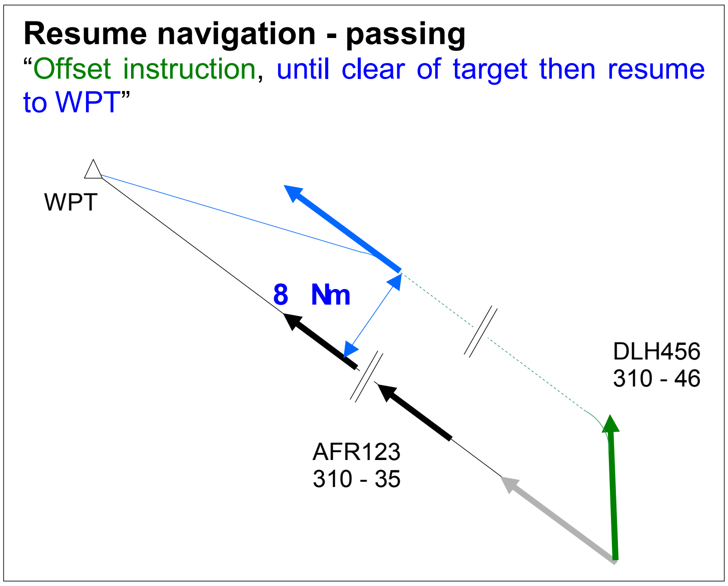
Colour Convention :

Black : actual situation of target aircraft | Green : controller instruction

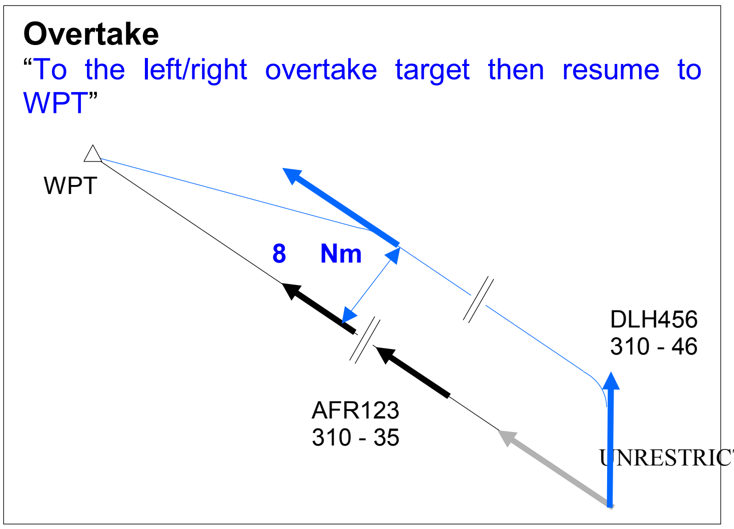
Grey : initial situation of delegated aircraft | Blue : delegated instruction

Dashed : predicted or potential situation

First Level:



Second Level:



3.1.3.6.4 Passing Phraseology

Resume navigation – lateral passing (First Level): **offset** … **until clear of target** then resume to WPT

- *Identification phase*
- Controller: "DLH456, fly right offset 5Nm (climb FL), until clear of target, then resume to WPT"
- Pilot: "Flying right offset 5Nm (then will climb FL) until clear of target, then will resume to WPT, DLH456"
- Controller: "AFR123, maintain heading (for spacing)"
  Then, once ahead of target:
- Pilot: "DLH456, clear of target, resuming to WPT"
- Controller: "AFR123, normal nav"

Overtake – lateral passing (Second Level): left / right **overtake** then resume to WPT

- *Identification phase*
- Controller: "DLH456, to the right, overtake target to the right (climb FL), then resume to WPT"
- Pilot: "Overtaking target to the right (then will climb FL), then will resume to WPT, DLH456"
- Controller: "AFR123, maintain heading (for spacing)"
  Then, once clear of target:
- Pilot: "DLH456 clear of target, resuming to WPT"
- Controller: "AFR123, normal nav"

3.1.3.6.5 General Lateral crossing and passing

This operational application can be flown manually by the flight crew, but it would be expected that, under en-route flight conditions, the aircraft would normally have the Automatic Flight Control System (AFCS) engaged and, most likely, the Flight Management System (FMS) would be providing the guidance demands. The AFCS lateral control mode would be either LNAV (using FMS commands to control to the route) or HDG (using a pilot-selected heading value). Similarly, altitude and speed control may be derived from the FMS or from pilot selections.

During the manoeuvre, the flight crew is required to maintain spacing between the aircraft to satisfy the delegated surveillance task. The controller is still responsible for separation assurance. In the case of the required distance or time not being achieved, the pilot should follow the defined escape/fallback procedures or ask for an alternative instruction.

When the crossing/passing/overtaking is completed, the flight crew advises the ATC controller via voice or CPDLC communications and the task of spacing is returned to the controller.

Safety net is to be integrated in the CDTI. Additional crew alerting system during the crossing/passing/overtaking manoeuvre is the Airborne Collision Avoidance System (ACAS). This will provide both an aural and graphical warning if it detects a possible collision situation.

3.1.3.7. Application Time Constraints

For the above benefits to be attained from this application, sufficient aircraft need to be equipped with a CDTI in order for the controller to be able to delegate the spacing monitoring task to the flight crew and thus improve airspace usage. Similarly, there has to be the aircraft data available for displaying on the CDTI and consequently either a reasonable proportion of aircraft need to be ADS-B equipped or the ground ATC systems need to be capable of providing TIS-B data. If only a few aircraft are equipped with CDTI, this application could be viewed as a special case condition and therefore could result in greater workload for the controller because it would not be regarded as a standard procedure.

The airborne situation is likely to incorporate a mix in the level of equipment fit on the aircraft and this will determine whether the controller will be able to delegate spacing tasks to the flight crew. The information on an aircraft's equipment fit (e.g. CDTI, ADS-B, etc.) needs to be available to the controller, probably via the originally filed flight plan. Finally, the flight crew have the right to not accept the delegation of the spacing task due to heavy workload.

New procedures will need to be defined in order for this application to be implemented within the ATM environment. This in turn will require additional training for both the controllers and the flight crew.

3.1.3.8. Information Exchanges

This application involves air/ground and air/air communications as well as the transfer of surveillance data either between aircraft (ADS-B) or relayed from the ground (TIS-B).

The received surveillance data relating to a surrounding aircraft that is required for this application consists of:

a) Call Sign
b) ICAO code
c) Position
d) Altitude
e) Ground Speed
f) Track Angle, Heading
g) Vertical speed

The last two parameters are useful but could be derived by comparing previous position and altitude reports.

The traffic information that is then displayed to the pilot via the CDTI needs to be defined relative to the own aircraft. This data for each traffic symbol on the display should consist of:

a) Call Sign
b) BICCA code (Conversion of the received ICAO code)
c) Relative Position
d) Relative or Actual Altitude
e) Indication whether Pass/cross
f) Track Angle, Heading

Additional information that should be available to the flight crew on selecting a particular traffic symbol is:

g) Relative Range
h) Relative Closure Rate or Actual Ground Speed
i) Additional warnings

The RTCA Paper No. 186-98/SC186-128 "Operational Concepts For Cockpit Display Of Traffic Information (CDTI), Initial Applications" defined possible air/ground and air/air radio communications messages that could be used for this application. Comparable datalink/ CPDLC messages would also need to be defined to complement the air/ground radio messages.

3.1.3.9. Exception Handling

Should the situation arise that ADS-B (or TIS-B) data is no longer available, the crew will be unable to continue to maintain the spacing, the application will be terminated. The spacing task is transferred back to the controller and the aircraft will be managed by ground based procedures.
In circumstances where the crew cannot continue to accept the delegated task for spacing, communication with ATC is to be carried out by radio due to the tactical nature of the situation.

System software should warn the crew if the spacing distance is lower than the required value, however, if an ACAS alert sounds, then this takes priority over the current manoeuvre and the crew must follow any avoidance instructions. The flight crew must also advise ATC by radio, since this will have cancelled any previous ATC instruction and spacing task must be returned to the controller once the ACAS event is resolved.

Similarly, if ATC issues any avoidance instructions, then these take priority over any other actions.

If communications failure occurs, the flight crew will continue to follow the current clearances and will adopt the standard communications failure procedures.

If an emergency occurs on the aircraft, the crew will follow the normal procedures and communications relevant to the situation.

3.1.3.10 Training Considerations

Pilots' and controllers' training is essential for proper use of the ASAS procedures and displays. Appropriate training requirements need to be defined, and course syllabuses developed, approved, and implemented.

Training aspects are critical and will have to be closely considered when:

- implementing a new application;
- extending a well-known application to a new operational environment; or
- modifying the operational environment.

Training aspects will focus on new relations and responsibilities between flight crews of different aeroplanes performing ASAS applications, and between flight crews and controllers.

3.1.4 Vertical Applications/ Crossing and Passing

3.1.4.1. Operations Service Description

This application concerns the delegation of responsibility for the spacing task from the ATC controller to the flight crew during a vertical manoeuvre, in which the own aircraft crosses or attains the altitude of another (target) aircraft that is flying level on a similar track to the own aircraft. This situation generally relates to airspace regions (e.g. oceanic or non-radar equipped managed airspace) where the standard separation criteria would not normally permit such a manoeuvre. This application can also be extended to operations in managed airspace regions with standard radar surveillance in order to help alleviate the workload of the controller. This type of transfer of task to the flight crew is known as limited delegation of spacing. Requirements for this transfer of task include the provision of a Cockpit Display of Traffic Information (CDTI) for the flight crew of the own aircraft and the broadcasting of aircraft state data from the target aircraft using ADS-B or from the ground ATC system using TIS-B. The CDTI allows the crew to monitor their aircraft's position relative to the surrounding traffic. This should provide the necessary airborne situational awareness to the crew. This can be improved further by using intent data, if available, from the surrounding air traffic. The controller would not necessarily require ADS-B information to delegate spacing task to the flight crew in regions without normal surveillance means, the main requirement is that the pilot can identify and monitor the relevant target aircraft on the CDTI. Provision of ADS-B data to the controller would however be beneficial to his/her situational awareness and would also be important if the controller is to be in a position to initiate this process.

The flight crew can initiate this application if it determines that a change in cruise altitude is required to improve the efficiency of the flight or to avoid adverse weather. A request is made to the ATC controller. Current air/ground voice communications would be adequate to satisfy this application, although it would be expected that CPDLC would be utilised, if available. In regions outside of normal radar coverage with limited means of independent surveillance, execution of the manoeuvre might infringe the minimum separation for this airspace if a neighbouring aircraft is on a similar track and different altitude. This will induce that the controller will stop the procedure and revert to ground based instructions. The crew uses the CDTI to verify that the spacing value and the relative closure rate to the other aircraft are within set tolerances, which in turn ensure that the minimum allowed separation distance should not be infringed during the climb or descent. These values are also defined to prevent the flight crew from having to continuously monitor the spacing condition throughout the manoeuvre. These conditions should enable the pilot to satisfy the requirements for monitoring the aircraft spacing by being able to include the CDTI within his/her normal scan of the instruments. These vertical manoeuvres can be either behind (known as in-trail climbs/descents) or ahead of (known as lead climbs/descents) the other aircraft. Although, the own aircraft is now responsible for monitoring its spacing from the target aircraft, ATC is still responsible for the separation assurance.

The controller may also initiate this process, either in airspace with normal radar coverage or where ADS-B information is being received from the aircraft to provide an adequate pseudo-radar picture. This decision will normally be the result of an anticipated conflict situation or to improve the traffic flow/airspace utilisation. The controller can use this application to help alleviate part of his/her workload by delegating the monitoring of the aircraft's spacing during a climb/descent manoeuvre to the flight crew.

It may not be necessary to inform the crew of the other (target) aircraft of the intended climb/descent manoeuvre since they are not expected to take any action. However, in non-radar equipped airspace where the operation may be below the normal separation standards, it could be sensible to advise the other crew who could witness the reduction in separation on their own CDTI (if it is suitably equipped). As well as advising the other crew of their intentions, this allows the own crew to confirm that the other aircraft will not be deviating from its current altitude, speed and track in the immediate future. On completion of the climb/descent manoeuvre, the flight crew will advise ATC and, if necessary, the crew of the other aircraft. In the case of the own aircraft now being at a different altitude to the target aircraft, responsibility for the monitoring of the aircraft's spacing is restored to ATC. If the aircraft is now at the same altitude as the target aircraft, then the responsibility for the spacing monitoring task is still retained by the flight crew until ATC instructs a change to the flight path of one of the two aircraft. This continued responsibility for monitoring the spacing of the own aircraft from the target aircraft is only to be maintained for certain duration. On reaching the co-altitude, the own flight crew must confirm that the spacing value and closure rate values are still within the defined limits. Otherwise, ATC are advised and a new clearance obtained to resolve the situation.

This service is an extension of the procedures, being investigated through operational trials, for the use of the TCAS II traffic display for in-trail climbs and in-trail descents in oceanic regions. The above service description is also based on that given in the RTCA Paper No. 186-98/SC186-128 "Operational Concepts For Cockpit Displays Of Traffic Information (CDTI), Initial Applications".

3.1.4.2. Scope and Objective

This application can be used within En-Route, Oceanic or Non-Radar Equipped Managed Airspace. Its primary use is within airspace where there is limited available surveillance information for ATC and/or where there is poor air/ground communications. It is typically related to operations within the cruise, but it might also be extended to operations in the climb and descent phase when conditions are appropriate. The target aircraft needs to be in level flight while the own aircraft can be either in the level or climbing /descending towards the altitude of the target aircraft. The problem with the case of the own aircraft being in the climb or descent is that this application can only really be implemented when the two aircraft are within a defined altitude range of one another (probably about 5000 or 6000 feet). This is partly because there could be a significant variation in the ground speed with altitude and therefore the closure rate would be affected as the aircraft climbs or descends. Therefore there may not be a reasonable time frame in which to complete the communication exchanges before the own aircraft has to level out at an earlier, previously cleared altitude.

The own aircraft needs to be equipped with a CDTI and to be able to receive broadcast state information concerning the target aircraft either via Automatic Dependent Surveillance - Broadcast (ADS-B) (air-derived) or Traffic Information Service - Broadcast (TIS-B) (ground-derived). This application requires the target aircraft to be equipped for ADS-B transmissions, if not then the ATC ground system must be able to supply the TIS-B data. In the case of the TIS-B data, the necessary surveillance information needs to be available to ATC. Air/ground voice communications do not require any modifications from the current equipment fit, although a channel may need to be allocated to allow air/air voice communications. This latter item would permit the crew of the target aircraft to be advised of the intended manoeuvre and therefore to improve their situational awareness. This is probably only important in airspace where the standard separation limits will be reduced for the duration of the climb or descent. Additionally, the crew of the own aircraft can check with the crew of the target aircraft that they are not intending to change their flight profile during the course of the proposed manoeuvre.

The main objective of this application is to increase the opportunity for aircraft to attain their most efficient cruise altitude or to avoid adverse weather in airspace regions under procedural control, which are beyond the normal surveillance coverage from the ground and/or have limited communications. In these regions where the required separation criteria are reasonably large, these altitude manoeuvres would possibly infringe the normal separation standards of this airspace. An additional objective of this application is to allow the controller to better utilise the capacity available within this airspace. The controller may also use this application in airspace regions with more normal surveillance coverage in order to help alleviate the workload. These objectives are derived from the description of function AS-28, In-trail application, from the MA-AFAS WP1.3 Functional Decomposition document.

3.1.4.3. Expected Benefits and Anticipated Constraints

Expected Benefits

The benefits of this application include greater flexibility and efficiency for flight operations in regions of limited ground surveillance and/or communications. Similarly, the controller's workload for handling an individual flight would be reduced due to the delegation of spacing tasks to the flight crew, resulting in less communication and monitoring activities for the controller. This reduction in controller workload per flight and the possibility of decreasing separation minima under certain conditions can also achieve an increase in the effective airspace capacity. An additional benefit is the greater opportunity to avoid adverse weather conditions and therefore provide as comfortable a flight as possible for the passengers.

Anticipated Constraints

For the above benefits to be attained from this application, sufficient aircraft need to be equipped with a CDTI in order to for the controller to be able to delegate the spacing monitoring task to the flight crew and thus improve airspace usage. Similarly, there has to be the aircraft data available for displaying on the

CDTI and consequently either a reasonable proportion of aircraft need to be ADS-B equipped or the ground ATC systems need to be capable of providing TIS-B data. If only a few aircraft are equipped with CDTI, this application could be viewed as a special case condition and therefore could result in greater workload for the controller because it would not be regarded as a standard procedure.

The airborne situation is likely to incorporate a mix in the level of equipment fit on the aircraft and this will determine whether the controller will be able to delegate spacing tasks to the flight crew. The information on an aircraft's equipment fit (e.g. CDTI, ADS-B, etc.) needs to be available to the controller, probably via the originally filed flight plan. Finally, the flight crew can refuse the delegation of the spacing task due to heavy workload.

New procedures will need to be defined in order for this application to be implemented within the ATM environment. This in turn will require additional training for both the controllers and the flight crew.

3.1.4.4. Human Factors

A CDTI needs to be situated in a position where the flight crew can easily view the display. Ideally, this would be provided via an overlay to the Nav display and therefore the CDTI would be in the pilot's primary field of view for head-down operations in the cockpit. This display should provide graphical representation of the location of surrounding aircraft relative to the own aircraft. Some form of logic would need to be applied within the display to ensure that it only shows aircraft within a certain height bound of the own aircraft (these height bounds may vary dependent on whether the own aircraft is climbing, descending or level). The information on the display should include the call sign, altitude and track of each aircraft. As an overlay on the Nav display, the traffic information should be selectable on or off by the pilot. Clearly, for this application, when the flight crew is responsible for the spacing task, the CDTI overlay would need to be permanently displayed.

This display should have an adjustable range control. It should also provide the capability to select one of the surrounding aircraft (probably by the use of a cursor-controlled device) and to display additional information relating to this target aircraft's spacing value and the relative closure rate with the own aircraft. This should be sufficient for the flight crew to perform the spacing task during the climb/descent manoeuvre.

For this application, the communication between the flight crew and the ATC controller can be either via voice or CPDLC (data link is not essential to this application). In the case of CPDLC, there must be some form of data link screen in the cockpit, which allows the crew to format the in-trail (lead) climb/descent request message and transmit this to ATC. Similarly, any ATC message will be shown on the CPDLC display with a capability for acknowledging their receipt. The controller will be similarly equipped to allow the formatting and acknowledgement of CPDLC messages associated with this application. The current library of proposed CDPLC messages would need to be extended to include in-trail/lead requests and clearances.

Some form of alerting function will also be available to warn the crew if it is predicted that the minimum allowed separation from the target aircraft is likely to be infringed. This alert will consist of an aural part to attract the crew's attention and a visual aspect on the CDTI.

3.1.4.5. Operating Method without Vertical Applications

Currently, the separation of aircraft operating in oceanic or non-radar-equipped airspace is defined in terms of large distances due to the lack of independent surveillance means. Under these conditions, it is necessary for pilots to radio their positions to the ATC controller at defined intervals or specified points along the route in order to provide the controller with some form of surveillance information. The levels of navigation performance and air/ground communications that are available in these regions are additional factors affecting the required separation distances. This type of airspace normally implements a fixed or flexible route structure. Lateral separation of routes is of the order of 60 to 100 nautical miles. An aircraft operating at the same altitude or crossing the level of another aircraft while on the same track is required to be separated from the other aircraft by at least 10 minutes longitudinally or by at least 80nm in an RNAV environment. There may also be a speed restriction; the delegated aircraft can be required to fly at a speed no greater than that of the preceding aircraft. Above FL290, aircraft are separated vertically by 2000 feet, but with the introduction of Reduced Vertical Separation Minima, this is being reduced to 1000 feet in certain areas.

To optimise an aircraft's fuel consumption or to avoid the effects of adverse weather, flight crews may request to ATC for a change in cruise altitude. Currently, due to these large separation distances that must be maintained, ATC may not be able to clear the manoeuvre because of the proximity of other traffic on a similar track and at an intervening flight level. Similarly, the controller will be restricted in his/her options for utilising the available airspace capacity.

In en-route airspace with normal radar coverage, the along-track separation for aircraft that are at or crossing the same altitude is dependent on factors such as the available ground-based navigation aids and the type of route structure being flown (e.g. fixed or RNAV). Typically, in areas with a good distribution of VOR and DME navigation aids, the separation minima would be 10 to 20 nautical miles. The controller is responsible throughout for monitoring the separation of the aircraft in his/her sector and for the detection and resolution of any conflicts. The pilot is responsible for the execution of the instructions from the controller.

Additional information is available within ICAO PANS Doc. 4444-RAC/501, Part III. Area Control Service.

3.1.4.6. Operating Method with Vertical Applications

This operational application can be flown manually by the flight crew, but it would be expected that, under en-route flight conditions, the aircraft would normally have the Automatic Flight Control System (AFCS) engaged and, most likely, the Flight Management System (FMS) would be providing the guidance demands. The AFCS lateral control mode would be either LNAV (using FMS commands to control to the route) or HDG (using a pilot-selected heading value). Similarly, altitude and speed control may be derived from the FMS (VNAV) or from pilot selections of altitude and speed.

This application can be initiated by either the pilot or the controller, depending on the situation that is encountered and the airspace involved. The pilot or controller may wish for a change in the aircraft's current altitude, possibly, in the case of the controller, to avoid some other traffic or, in the case of the pilot, to utilise more favourable wind conditions. If another aircraft is flying a similar track to the own aircraft and this change in altitude will cross or attain that of this other aircraft, then an in-trail/lead climb or descent could be implemented. An in-trail climb/descent is where the target aircraft is ahead of the own aircraft, while a lead climb/descent is where the target aircraft is behind the own aircraft. Communication between the pilot and controller can be via voice or CPDLC. Following the pilot's request or based on his own decision, the controller may send a clearance to the aircraft for the in-trail/lead climb or descent, including the call sign of the target aircraft if this is being initiated by the controller. The pilot will identify this aircraft on the CDTI and will select it (using a cursor-controlled device?), obtaining information on the spacing value and the relative closure rate. Providing that the spacing is greater than a defined minima (*TBD*) and the closure rate is not greater than a set value (*TBD*), then the situation is suitable for an in-trail or lead climb/descent to be performed. If the intention is to attain the same altitude as the other aircraft, then this rate limit will be much lower to prevent the separation being reduced significantly at completion of the manoeuvre. The pilot will then confirm to the controller that the climb/descent is to be executed. This also confirms that the pilot is accepting responsibility for monitoring the spacing of the two aircraft during the course of the manoeuvre.

This application may require the pilot to communicate with the target aircraft via radio to advise the other crew of the intentions of the own aircraft, depending on the type of airspace in which the aircraft are operating. If they are within normal radar-controlled airspace and the vertical manoeuvre will not infringe the standard separation distances for this airspace, then there may be no real reason for communicating with the other crew. It might be advisable to inform the other crew : this communication can be used to ensure that the target aircraft is not intending to change speed, heading or altitude in the immediate future.

If instruction is received from ATC, the pilot can update the cruise altitude in the FMS or directly enter this altitude via the AFCS control panel. This will then automatically perform the required climb or descent. During the manoeuvre, the flight crew is required to maintain a suitable monitor of the spacing between the aircraft to satisfy the delegated spacing task. The crew must also ensure that the climb or descent rate is above a defined limit (*TBD*). In the case of the required rate not being achieved, the pilot must request clearance from ATC for a new altitude or a return to its original altitude.

On reaching the assigned altitude, the flight crew advises the ATC controller via voice or CPDLC communications. If this is a different altitude to that of the other aircraft, then the operation is complete and the responsibility for separation monitoring will transfer back to the controller. If the manoeuvre is to the same altitude as the other aircraft, the task of spacing remains delegated to the flight crew until ATC instructs a further change to the flight path of either aircraft. On reaching the co-altitude, the flight crew must re-confirm the spacing and closure rate relative to the target aircraft to ensure that these are still within the operational limits. The crew should also advise the crew of the other aircraft via radio, if this was done prior to the manoeuvre, when the climb/descent is complete.

To provide a crew alerting system during the in-trail/lead manoeuvre, the CDTI could include a function to detect if the spacing distance between the own aircraft and the target aircraft (previously selected using the cursor-controlled device) is predicted to fall below a minimum value. This prediction could be determined using the current separation distance and altitude, the closure rate and a defined time constant. If loss of separation is anticipated, then an aural warning should be generated to attract the crew's attention and the colour of the target aircraft changed to red (or some appropriate colour) on the CDTI. Once the manoeuvre is complete, the pilot should de-select the target aircraft on the CDTI in order to disable the alerting function. The Airborne Collision Avoidance System (ACAS) provides an additional safety net process in case the standard alerting feature fails. If ACAS issues a resolution advisory instruction then the pilot will be required to obey this instruction, returning to the original clearance if possible once clear of the threat. After initiating an ACAS avoidance manoeuvre, the pilot should contact ATC by voice to advise the controller of the situation in case a new clearance is now required. The alerting function for this application should operate at a greater threshold than that used by ACAS and therefore it is not required to provide conflict resolution information.

A similar alerting system will be available to the controller on the ground as well, although the form of this will need to be established in order to be consistent with other applications.

3.1.4.6.1 List of Functions Involved in Vertical Applications

The following is a list of functions, derived from the table produced as part of WP1.3, which are associated with Vertical Applications.

a) Import Surveillance (AS-04) and Airborne Surveillance Data Processing (AS-05):
These are required to manage the received traffic information that is broadcast either from other traffic using ADS-B or from the ATC ground system using TIS-B. This is likely to include the determination of spacing value and closure rate information. The function Export Information

(AS-33) might also be included, but this application is really only concerned with the own aircraft receiving data and is not necessarily reliant on it transmitting surveillance data.

b) Cockpit Display of Traffic Information (AS-01), Target Identification (AS-12), Target Selection (AS-13) and Delegation Parameters (AS-14):
These functions provide the mechanism for displaying surrounding traffic to the pilot and for allowing him/her to interface with this display. This interface requires the ability to identify and to select (via a cursor-controlled device?) a particular target aircraft on the CDTI. There is also a function called Confirmation of Target Selection (AS-35) which may also be relevant, but at the moment it is not entirely clear what this function actually does and therefore if this application is dependent on it.

c) Co-operative Spacing Establishment/Maintenance (AS-07), Instruction Delivery from Controller to Pilot (AS-08) and Air/Air Cross Check (AS-09):
These functions are utilised by this application to provide the means of obtaining instruction from the controller and for the pilot to perform the required task. These functions are assumed to include the delegation of the spacing task to the pilot. The Co-operative Spacing function appears to be directed more at the Longitudinal Spacing application, but the basic aspects of this function are relevant to this application, the requirement being to maintain spacing within certain bounds as opposed to a fixed time or distance value. The Air/Air Cross Check function concerns the situations when the own aircraft advises the target aircraft of its intentions (this may be removed if it is decided that the circumstances of this application do not require air/air communications).

d) Alarming (AS-34):
The application will include some form visual and aural warning to the pilot when it detects that the minimum allowed spacing value to the target aircraft is to be infringed.

Additional Communications functions that are associated with this application consist of CPDLC (CO-43), TIS-B (CO-50), ADS-B (CO-51) and Voice Comms. (CO-65). However, these are considered as constituents of the above ASAS/CDTI functions.

3.1.4.6.2 Vertical Applications Phraseology

The following phraseology for the pilot-controller voice communication for an in-trail climb is based on that proposed in the RTCA Paper No. 186-98/SC186-128, Operational Concepts for CDTI, Initial Applications. These messages will need to be modified in order to ensure consistency with those proposed for other similar applications such as Level-Fligth-Spacing and In-Descent-Spacing.

Once the pilot has identified the target aircraft ahead of the delegated aircraft, then he/she calls ATC to request the climb:
"<ATC facility>, <own call sign> is X miles in-trail of <target BICCA code (converted ICAO code)>. Request in-trail climb to FL ABC."
The controller response would be:
"<Own call sign>, climb to and maintain FL ABC. Report reaching FL ABC."
The pilot reads back the clearance:
"<ATC facility>, <own call sign>, out of FL DEF for FL ABC. Will report reaching."
Prior to actually starting the climb, the flight crew will ensure that the spacing value and closure rate to the target aircraft are within the required bounds.
After reaching the cleared level, the pilot reports:
"<ATC facility>, <own call sign>, level at FL ABC."

If the delegated aircraft was ahead of the target aircraft then the initial request from the pilot would have been:

"<ATC facility>, <own call sign> is X miles in-front of <target BICCA code>. Request lead climb to FL ABC."

Similarly, if the pilot wished to descend, then the word "climb" would be replaced by "descent" in the above messages.

If the controller initiates the in-trail climb, then the communication dialogue may consist of the following. Initially, the controller requests the pilot to select the appropriate target aircraft on the CDTI.

"<Own call sign>, <ATC facility>, select target <target BICCA code (converted ICAO code)>."

The pilot would then acknowledge having selected this target.

"<ATC facility>, <own call sign>, identified target <target BICCA code>."

The controller then instructs the delegated aircraft to perform an in-trail climb.

"<Own call sign>, in-trail climb to and maintain FL ABC. Report reaching FL ABC."

The pilot confirms initial conditions on CDTI and acknowledges clearance to climb.

"<ATC facility>, <own call sign>, out of FL DEF for FL ABC. Will report reaching."

After reaching the cleared level, the pilot reports:

"<ATC facility>, <own call sign>, level at FL ABC."

If the crew of the delegated aircraft is required to contact the crew of the target aircraft, then the contact message would consist of:

"<Target call sign>, this is <own call sign>, we are X miles in-trail and will climb through your altitude to FL ABC."

The acknowledgement message from the target aircraft (at FL JKL) would be:

"<Own call sign>, <target call sign>, understand you will be climbing through FL JKL. Thank you."

Corresponding CPDLC messages would need to be defined to match these voice messages, except for the air/air ones.

Interaction with Other Applications

The following applications could be active either at the same time as or directly before or after this application. With other applications, there is no expected interaction with Vertical Applications.

a) Level Flight Spacing:

The target aircraft could be the final delegated aircraft involved in Level Flight Spacing while the own aircraft performs an in-trail climb or descent. Similarly, the target aircraft could be the target aircraft for Level Flight Spacing while the own aircraft performs a lead climb or descent. With other configurations, it would be unlikely that there would be sufficient distance between Level Flight Spacing aircraft to allow an in-trail/lead climb or descent to occur between them. One problem for the in-trail situation is that the target aircraft carrying out Level Flight Spacing might change its speed to match the target Level Flight Spacing aircraft and this could affect the spacing distance to the delegated aircraft during its in-trail climb. It is also possible for an aircraft to transition between in-trail/lead climb or descent and Level Flight Spacing. This might be required for an aircraft performing an in-trail descent to the co-altitude with the target aircraft.

b) Lateral Crossing:

Although in theory this could be permissible, it is difficult to envisage that the target aircraft could be performing a lateral crossing manoeuvre while the own aircraft is carrying out an in-trail/lead climb or descent. The problem is that the own and target aircraft are required to be on similar tracks. If the target aircraft changes its lateral path, then this could directly affect the spacing distance and/or closure rate relative to the delegated aircraft.

c) Autonomous Operation:

Vertical Applications and Autonomous Operation cannot exist in parallel, because the first is related to managed airspace and the latter to free-flight airspace. It could occur, however, that, at the transition between these types of airspace, the own aircraft could transition between these two types of application.

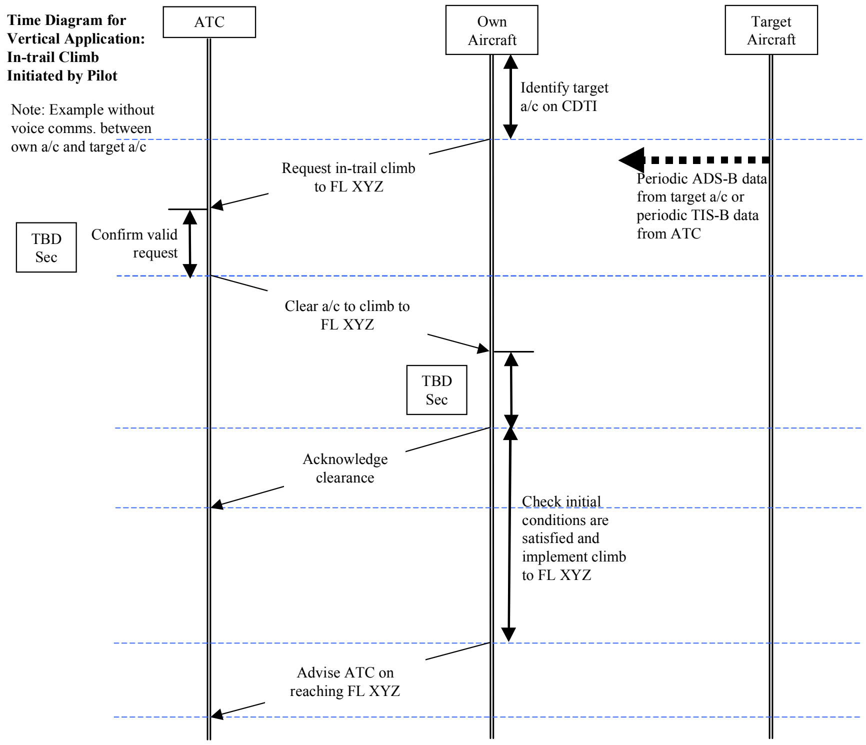
d) 4-D Negotiation:
This application can occur at the same time as the own aircraft is performing an in-trail/lead climb or descent. This assumes that the 4-D trajectory being negotiated reflects the aircraft's currently cleared change in altitude. Similarly, the target aircraft could also be involved in 4-D negotiation.

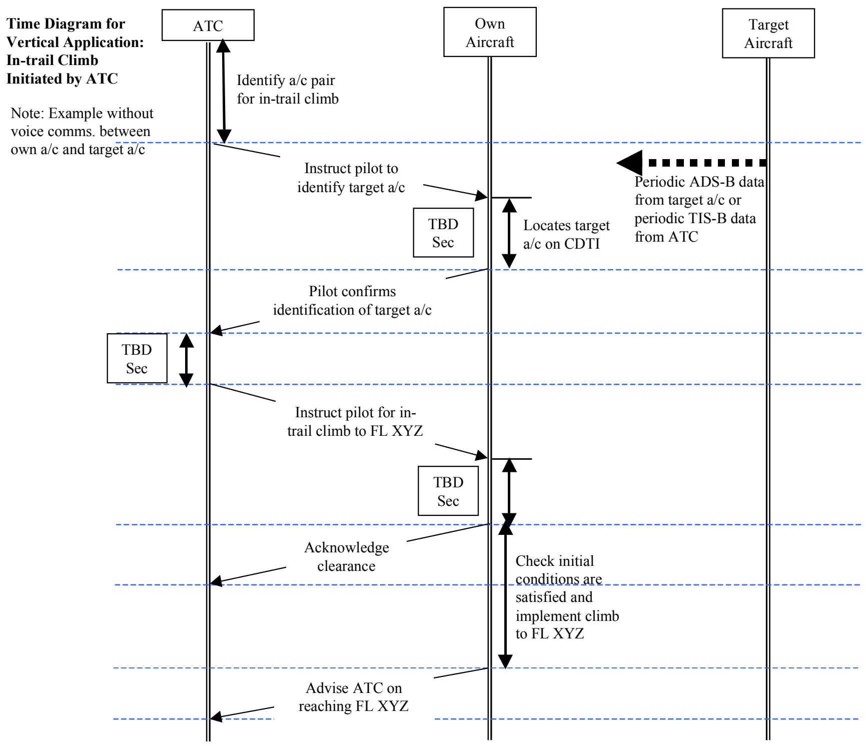
e) 4-D Navigation:
This application can be used to fly the in-trail/lead climb or descent manoeuvre, providing that the predicted 4-D trajectory maintains the delegated aircraft at greater than the minimum allowed spacing from the target aircraft. Similarly, the target aircraft may also be performing 4-D Navigation. It may be necessary to monitor any speed variations that may result during the 4-D Navigation process with either aircraft in case this increases the relative closure rate.

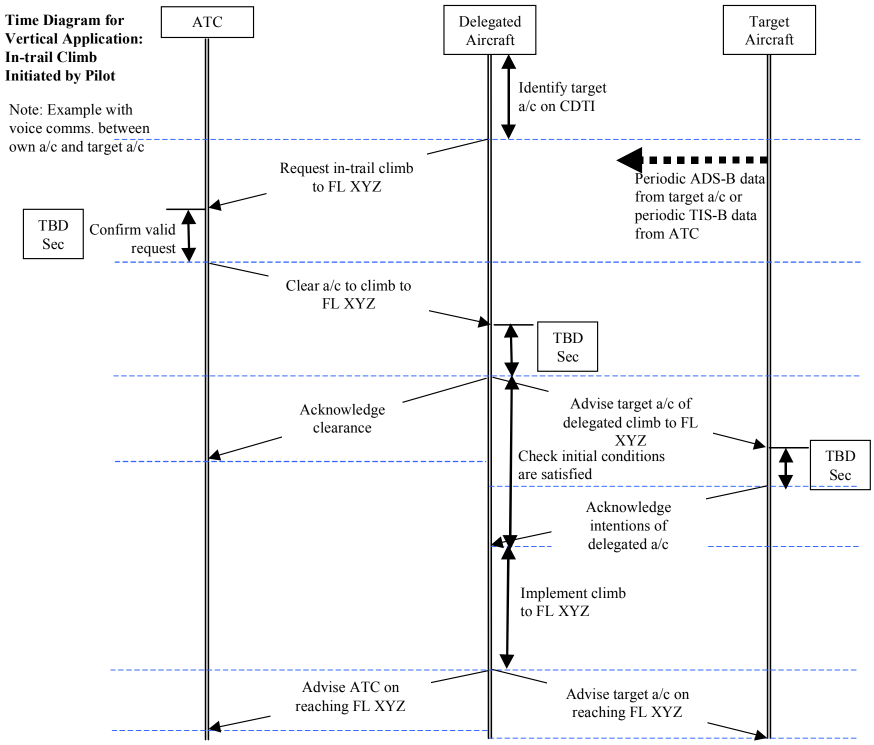
3.1.4.7. Application Time Constraints

The application of in-trail (lead) climbs/descents is strategic in nature and associated communications can therefore be handled by data link (CPDLC) if available. This application is only likely to be implemented in airspace in which the traffic situation is not changing rapidly and therefore the delegation of spacing task to the air crew can be achieved safely. Combined with the required minimum initial spacing distance and maximum permitted closure rate for the manoeuvre, this means that there are no urgent time constraints concerning the air/ground communications exchange under normal conditions.

The following are examples of time diagrams for this application. These show a dialogue initiated by the pilot, another initiated by the controller and the final one represents a dialogue including air/air communication with the target aircraft.


Time Diagram for Vertical Application: In-trail Climb Initiated by Pilot
Note: Example without voice comms. between own a/c and target a/c
ATC
Own Aircraft
Target Aircraft
Identify target a/c on CDTI
Request in-trail climb to FL XYZ
Periodic ADS-B data from target a/c or periodic TIS-B data from ATC
TBD Sec
Confirm valid request
Clear a/c to climb to FL XYZ
TBD Sec
Acknowledge clearance
Check initial conditions are satisfied and implement climb to FL XYZ
Advise ATC on reaching FL XYZ


Time Diagram for Vertical Application: In-trail Climb Initiated by ATC
Note: Example without voice comms. between own a/c and target a/c
ATC
Own Aircraft
Target Aircraft
Identify a/c pair for in-trail climb
Instruct pilot to identify target a/c
Periodic ADS-B data from target a/c or periodic TIS-B data from ATC
TBD Sec
Locates target a/c on CDTI
Pilot confirms identification of target a/c
TBD Sec
Instruct pilot for in-trail climb to FL XYZ
TBD Sec
Acknowledge clearance
Check initial conditions are satisfied and implement climb to FL XYZ
Advise ATC on reaching FL XYZ



The application is also affected by the latency in and accuracy of the data displayed to the pilot on the CDTI. The latency issue is more directly concerned with the received ADS-B and TIS-B data than the update rate of the delegated aircraft's position. It is assumed that the position solution for the delegated aircraft will be updated within at least 1 second. This application is likely to be able to accommodate latency in the position information for the surrounding traffic of no more than about 4 seconds before errors could start to become significant. This is, however, related to the initial spacing value and maximum closure rate values that are permitted and also the minimum allowed separation distance that must not be infringed during the climb/descent manoeuvre. Therefore this latency value may need to be revised. The latency includes not only the frequency at which updated information is received via ADS-B or TIS-B but also the frequency at which this data is used to refresh the CDTI. It would be expected that the CDTI data should be refreshed at least once per second. It might be possible for the CDTI to extrapolate previous reports from other aircraft on each refresh if no new update has been received.

The accuracy of the position data used by the CDTI is also important to this application. The position data should have a resolution of at least 0.1nm (about 200m.) in order for the pilot to be able to monitor the spacing of the aircraft down to a value of possibly only a few miles. The accuracy of the position solutions is critical to the effectiveness of this application because it will influence the minimum spacing distances that can be used. This in turn will affect the opportunities for implementing this application. Since this application is aimed at areas where there is no radar coverage, the likelihood is that these areas will also have minimal ground-based navigation aids. It is assumed that satellite navigation systems will probably be used to enhance onboard inertial systems in order to provide position solutions with errors that are well below 1nm (probably less than 0.1nm). The Required Navigation Performance (RNP) for operations in the airspace can also be associated with this application because the application is concerned with the accuracy of the position solution being broadcast for a target aircraft. The RNP value will influence the type of navigation equipment that needs to be fitted and therefore has an association with the level of positional accuracy that should be achievable. An RNP value of 1 or better would certainly be adequate for this application. An RNP value of 5, however, could result in greater separation distances needing to be assumed. Similarly, if aircraft need to be RVSM compliant to operate in the airspace, then this would provide a greater flexibility for implementing this application due to the increased number of available cruise flight levels.

There are in effect time constraints that also relate to the actual execution of the climb/descent manoeuvre. If a minimum climb/descent rate cannot be achieved (values of 300 fpm climb rate and 1000 fpm descent rate have been defined for the equivalent TCAS II in-trail operations), then the air crew must request a new clearance from ATC to recover to a safe altitude.

3.1.4.8. Information Exchanges

This application involves air/ground and air/air communications as well as the transfer of surveillance data either between aircraft (ADS-B) or relayed from the ground (TIS-B).

The received surveillance data relating to a surrounding aircraft that is required for this application consists of:
a) Call Sign
b) ICAO code
c) Position
d) Altitude
e) Height Rate
f) Ground Speed
g) Track Angle
The last three parameters are useful but could be derived by comparing previous position and altitude reports.

The traffic information that is then displayed to the pilot via the CDTI needs to be defined relative to the own aircraft. This data for each traffic symbol on the display should consist of:
a) Call Sign
b) BICCA code (converted ICAO code)
c) Relative Position
d) Relative or Actual Altitude
e) Indication whether level, climbing or descending
f) Track Angle
g) Additional information that should be available to the flight crew on selecting a particular traffic symbol is:
h) Relative Range
i) Relative Closure Rate or Actual Ground Speed

The RTCA Paper No. 186-98/SC186-128 "Operational Concepts For Cockpit Display Of Traffic Information (CDTI), Initial Applications" defined possible air/ground and air/air radio communications messages that could be used for this application. Comparable CPDLC messages would also need to be defined to complement the air/ground radio messages.

3.1.4.9. Exception Handling

Should the situation arise that ADS-B (or TIS-B) data is no longer available, the crew will be unable to continue the spacing monitoring task and this will be transferred back to the controller. ATC will then, if necessary, provide instructions to the aircraft to ensure that the standard separation required for the airspace is re-established.

Similarly, if the aircraft climb/descent performance cannot be maintained above the minimum required rate, then as far as ATC is assuming responsibility for separation, he will give clearance instructions to the flight crew to resume normal separation.

If the alert associated with this application is triggered, then the crew may be able to modify the aircraft's speed or height rate in order to compensate and continue the climb or descent. Otherwise, the crew will need to contact ATC to request a revised clearance.

In circumstances where the crew cannot continue to accept the delegated responsibility for monitoring spacing, communication with ATC is to be carried out by radio due to the tactical nature of the situation.

If an ACAS alert sounds, then this takes priority over the current manoeuvre and the crew must follow any avoidance instructions. The flight crew must also advise ATC by radio, since this will have cancelled any previous ATC clearance and spacing task must be returned to the controller.

Similarly, if the ATC issues any avoidance instructions, then these take priority over any other actions.

If communications failure occurs, the flight crew will continue to follow the current clearances and will adopt the standard communications failure procedures.

If an emergency occurs on the aircraft, the crew will follow the normal procedures and communications relevant to the situation.

3.1.5 Autonomous operation

3.1.5.1 Operations service description

This section describes the autonomous operation application within the ASAS/CDTI theme as defined in the MA-AFAS project.
Basically three different distributions of the roles of assuring separation can be distinguished between ATC and the cockpit:

- Fully ATC's role
- Spacing task temporarily delegated to the cockpit
- Fully cockpit's role

It is the last one that will be highlighted here as this covers the autonomous operation.

The autonomous operation application will have, amongst others, requirements for communication, navigation and surveillance.

3.1.5.2 Scope and objective

Leaving the role of separation fully to the cockpit will require adaptation of the onboard equipment as well as the operating procedures by the crew and ground. Enabling the crew to perform the task of self separation requires communication means for surveillance to provide the crew with information about the surrounding traffic, functionality to detect future traffic conflicts and support to resolve these conflicts.
The essence of autonomous operation is that flight crews are able to maintain separation without assistance from the ground during normal operation. In order to achieve this type of operation, the crew should be aware of situations in which separation is expected to be lost and to be sure that the crew of the intruder aircraft is also aware of this situation. Subsequently both crews should know how to act in this situation based on defined procedures, often referred to as 'rules of the air' which apply in FFAS only. On board systems might have these rules of the air incorporated in their functioning or it might be completely human operated, depending on the chosen concept.

3.1.5.3 Expected benefits, anticipated constraints

Expected benefits

Autonomous operation is expected to create an increase in airspace capacity and in safety due to its de-centralised character. The responsibility of separation assurance within a certain airspace is no longer the responsibility of one person (the tactical controller) but is the shared responsibility of the pilots-in-command of all aircraft in that airspace, so no longer a centralized air traffic control system but a distributed system. New airborne tasks are the result of this shift in responsibility, the most important one deals with conflict detection and resolution.
Direct routing is the main reason for a change in the separation task, a task change from mainly structuring traffic flows to detecting and resolving conflicts. Since the capacity of an en-route sector is nowadays already limited by the workload of the controllers, it is even more difficult to increase capacity in a direct routing structure in a centralized system. In a distributed system the conflicts, which had to be detected and resolve by a very limited number of controller in a centralized system, now are distributed over all flight crews in the applicable airspace. The flight crews only deal with their own conflicts and have their own conflict rate that differs from the overall conflict rate. Note that in a centralised system it is the overall conflict rate the controllers have to cope with. The conflict rate experienced by each flight crew is much lesser than the overall conflict rate, moreover, this ratio will even drop as traffic density (i.e. number of conflicts) increases. Therefore, it can be concluded that the pilot workload will now become the limiting factor instead of the controller workload. Although a pilot can not put the same effort in this task as a controller, it has been found that a distributed system could handle more aircraft than controllers could. It is assumed that the limiting factor (pilot workload vs. controller workload) is an important factor. As a consequence airborne conflict management might enable airspace capacity growth while maintaining the current level of safety or alternatively increase the level of safety while maintaining the current airspace capacity. The distribution between capacity and safety is however a political choice.

Anticipated constraints
One of the basic elements of autonomous operation is conflict detection. This detection is performed using ADS-B information of surrounding traffic. In order to be able to meet the separation minima, the accuracy and validity of detected conflicts must be sufficiently high. The update rate of ADS-B messages from surrounding traffic is important and the ADS-B technology chosen must be able to support a sufficiently high data link throughput. An anticipated constraint is insufficient ADS-B bandwidth when flying in high density FFAS.

In addition to this, the ADS-B range is also a constraint which limits the look ahead time for conflicts. One of the more critical situations are head-on conflicts.

Conflict resolution is a basic element of autonomous operation in which the look ahead time and the required pilot decision/reaction times are constraining.

Regarding pilot workload, it is expected that workload is not increased compared to current ATC controlled flight. The conflict management task is added for the crew, but the radio telephony communication with ATC is minimised

Another anticipated constraint of the concept of autonomous operation is the behaviour of the individual pilots. In a centralised system as the current day ATC system, the Controller is controlling the traffic situation and pilots behaviour is directly observed by the Controller, which serves intended or unintended as an authority. In a distributed system as autonomous operation is, this link with an authority is less obvious and undesirable behaviour by pilots might be anticipated as a constraint of the concept. This might therefore lead to additional measures in case of non adherence to the rules of the air by crews .

Autonomous operation is not foreseen to be useable up to the landing runway. In other words, before landing, MAS will be entered again. This transition from a de-centralised system towards a centralised system will constrain the operation. The relatively un-organised situation existing in FFAS has to converge into a well organised traffic stream in order to make it possible for the Controller to take over the inbound traffic stream.

3.1.5.4 Human factors
A number of human factors issues are relevant regarding autonomous operation. Since not only some new equipment is used in the aircraft but the complete operation will change with different task distribution between the air and ground, but also between the two crew members. This applies also for ATC. FFAS is not equal to UMAS. In FFAS a Controller might be available, not being tasked to separate aircraft actively, but to fulfil a new task. This could be a task as arbiter, providing support in case of aircraft experiencing mal functions.
Summarising, the human factors issues for both air and ground will include:
- new system functions, including HMI;
- new procedures;
- new training requirements.

Airborne
Regarding crew tasks, the pilots are tasked to perform the separation task using a flight deck tools presenting traffic conflicts, priority situation if applicable and a conflict resolution manoeuvre in the event of conflict situation. This will mean that new equipment will be used and needs to be trained, but also new crew procedures, not applicable sofar, need to be applied. Against this new task of self separation, the communication task with Controller will decrease significantly. Communication with ATC is only relevant in case of non-nominal cases and while preparing to re-enter MAS. Communication with ATC during self separation is not foreseen other than for information services.

Regarding new flight deck instrumentation, the conflict detection and resolution algorithms and the presentation of the outcomes should be in all cases unambiguous, quickly and easy interpretable. The result of the conflict detection and resolution algorithm will be presented on the flight deck. Also surrounding traffic within a certain area around the aircraft might be presented, but this is optional. Raw data in this sense will only serve as background information and will never be used for separation tasks.

Ground
In FFAS the Controller might have a supporting role. Separation is performed by aircraft, but in case aircraft experience problems which leads to a situation in which the crew needs to focus purely on the technical problems on board the aircraft ATC should be capable in supporting in the separation task. In case the Controller is tasked to take over some kind separation activity for an individual aircraft experiencing problems of some kind, the Controller will require a radar image with appropriate tools to perform this task. In no case the Controller will be required to take over the complete traffic situation in the sector because the free flight traffic situation is not structured in a way the Controller would need. In addition, the capacity of a sector with autonomous operation might exceed the capacity of the same sector under ATC control. Therefore an Controller will not be able to take over the complete traffic situation, but only support individual aircraft. A type of tool which will be considered in the framework of MA-AFAS is an aircraft oriented view for the Controller. This will give the opportunity to select one aircraft and perceive the point of view from this aircraft which needs support. This support can be either direct to this crew, or by providing advisories to surrounding traffic.
Support from ATC will be most likely in regions as Europe. In oceanic regions it is less likely to require ATC available.

3.1.5.5 Operating method without operation application
Operating without the autonomous operation function is the current type of air traffic control. This means that the separation task is fully for ATC. Aircraft have no knowledge of surrounding traffic apart from the party line effect of R/T (TCAS is not considered in this sense as a separation tool, but purely a safety net). Aircraft have R/T communication with an ATC centre for the airspace sector they are currently operating in. ATC performs the separation task using a radar image of the traffic situation, or in case the sector is not under radar coverage, traffic is separated using procedures. FFAS is non existing.

3.1.5.6 Operating method with operation application
Two types of autonomous operation have been selected in the MA-AFAS project: the co-operative conflict resolution procedure and the priority rule based conflict resolution. For both applies that the resolution method becomes relevant after a conflict has been detected. Regarding conflict detection, both state and intent will be used. Intent in this sense means intent which is actually used for the control of the aircraft. This can be either a FMS route, auto pilot settings, or even none.

Co-operative conflict resolution
Co-operative conflict resolution is characterised by the fact that the two aircraft which are in conflict both take action by manoeuvring in order to solve the conflict. Initiating a manoeuvre in a way the conflict is indeed resolved and not worsened must be assured by proper rules which apply for all airspace users. Monitoring whether the conflict is indeed being solved by monitoring ADS-B reports from the intruder by system or human during the resolution process is required.

Priority rule based conflict resolution
Priority rule based conflict resolution is characterised by the fact that only one of the two conflicting aircraft is manoeuvring to solve the conflict. In this situation other ‘rules of the air’ exists which define which aircraft has priority over the other in a conflict situation. Once the priority has been determined the aircraft having priority is not required to manoeuvre as long as the conflict situation exist. The aircraft not having priority should initiate a manoeuvre which solves the conflict. How this manoeuvre looks like is not bound to any rule during normal operation as long as the protected zone of the priority aircraft is not

intruded. In case the priority determination process could not be concluded for some reason, a manoeuvre should be initiated which will be bound to some restrictions.

Co-ordination for conflict resolution
There are different types of co-ordination. Conflict confirmation is a form of co-ordination that may be required. In general co-ordination means conflict resolution co-ordination. In case of using priority rules, one could argue it is important to verify the understanding of who has right of way, for instance by explicitly co-ordinating this either on a system-level or on a human level. In case of no priority rules, one can imagine it is required to avoid counteracting manoeuvres by explicit (by communication) or implicit (by rules) co-ordination (again on a system level or crew level). The drawbacks of explicit co-ordination are in both the priority or no-priority concept:

- The wait traps, extra time is consumed while waiting for the co-ordination cycle which could be a missed message or other asymmetries
- Bandwidth, it requires a peer-to-peer connection. By broadcasting co-ordination messages valuable bandwidth of all aircraft in range is used.
- Added complexity, this has numerous drawbacks: lack of transparency for user, higher probability of failures, harder to certificate.

Therefore co-ordination should only be implemented when required. Implicit co-ordination could possibly remove the need for explicit co-ordination. In car traffic a common understanding of the rules of the road avoids extra co-ordination. Similarly this could be achieved in the air if the conflict resolution module can use the geometry of a conflict and apply rules to it. This is called "implicit co-ordination". The co-ordination took place when the rules were accepted. However, data uncertainties and discrepancies will be part of the real environment and therefore will have to be taken into account. This might result in aircraft having different views of a situation and possibly applying the rules differently. Analysis has to determine whether or not this effect is serious enough to justify explicit co-ordination. "Explicit co-ordination" means the co-ordination takes place at the moment of the conflict.

Combined priority rule based and co-operative conflict resolution.
Within MA-AFAS a combination of priority rule based and co-operative conflict resolution will be applied. Priority rule based conflict resolution is in the context of MA-AFAS defined as the technique in which aircraft solve a conflict according to a sequence order and with use of a planning resolution strategy. Co-operative conflict resolution is defined as the method in which aircraft solve a conflict simultaneously and with use of a reactive resolution strategy. The use of intent will make it possible to detect conflicts with a relative long look ahead time allowing for a priority rule based resolution. When a conflict however is not solved after a certain time or in the event that a conflict is detected with a relative short time to conflict, the co-operative resolution will be used. The latter because it is a more natural to manoeuvre both aircraft due to the shorter time frame to the conflict.

The nominal way in which a conflict is being solved will have the following sequence of events:

- *Both aircraft transmit their state and intent up to at least the look ahead time*

1. A conflict is detected by the system, but the time to conflict is larger than the look ahead time, so the crews are not alerted
   - *The conflict still exists and the time to conflict is shorter than the look ahead time*
2. The priority is determined based on the geometry of the two flight paths
   - *If explicit co-ordination is used, the outcome needs to be awaited*
3. The aircraft which has no priority determines a resolution
4. The crew of the aircraft which has no priority is now alerted and the resolution manoeuvre is presented to the crew
5. The crew reviews this resolution, and possible adapts it if deemed necessary
6. The aircraft having no priority manoeuvres
   - *Conflict is solved*
   - *The crew having priority is not alerted during this sequence of events*

In the case that the crew is not responding for a certain while the following sequence of events will occur:

- *Both aircraft transmit their state and intent up to at least the look ahead time*

1. A conflict is detected by the system, but the time to conflict is larger than the look ahead time, so the crews are not alerted
   - *The conflict still exists and the time to conflict is shorter than the look ahead time*
2. The priority is determined based on the geometry of the two flight paths
   - *If explicit co-ordination is used, the outcome needs to be awaited*
3. The aircraft which has no priority determines a resolution
4. The crew of the aircraft which has no priority is now alerted and the resolution manoeuvre is presented to the crew
   - *The crew is not taking action, or taking late action*
5. The time to conflict is detected to be less than the threshold time
6. The crew having priority is now alerted and a resolution manoeuvre based on the co-operative method is presented as well
7. The crew having no priority is again alerted and a new resolution is presented based on the co-operative method
8. The crews review this resolution and if deemed necessary adjusts it, however within the limits of the rules which apply for co-operative resolution
9. Both aircraft manoeuvre
   - *Conflict is solved*
   - *The crew not having priority should have manoeuvred in both phase 1 (priority rule based) and in phase 2 (co-operative), but if not taken any action the conflict is fully solved by the crew initially having priority. Not taking action might lead to corrective actions from authorities for example by means of a fine.*

In the case the conflict is detected when the time to conflict is less than the threshold time, for whatever reason (for example only state information is available), the following sequence of events will occur:

- *Both aircraft send out their state and possible some intent*

1. A conflict is detected by the system, the time to conflict is smaller than the look ahead time and also smaller than the threshold time, but significantly larger than ACAS trigger times
2. Both crews are alerted and both crews are provided by their system with a resolution
3. Both crews review this resolution and if deemed necessary adjusts it, however within the limits of the rules which apply for co-operative resolution
4. Both aircraft manoeuvre
   - *Conflict is solved*

The times mentioned in the above sequences of events are still to be determined but the first values used within MA-AFAS are:

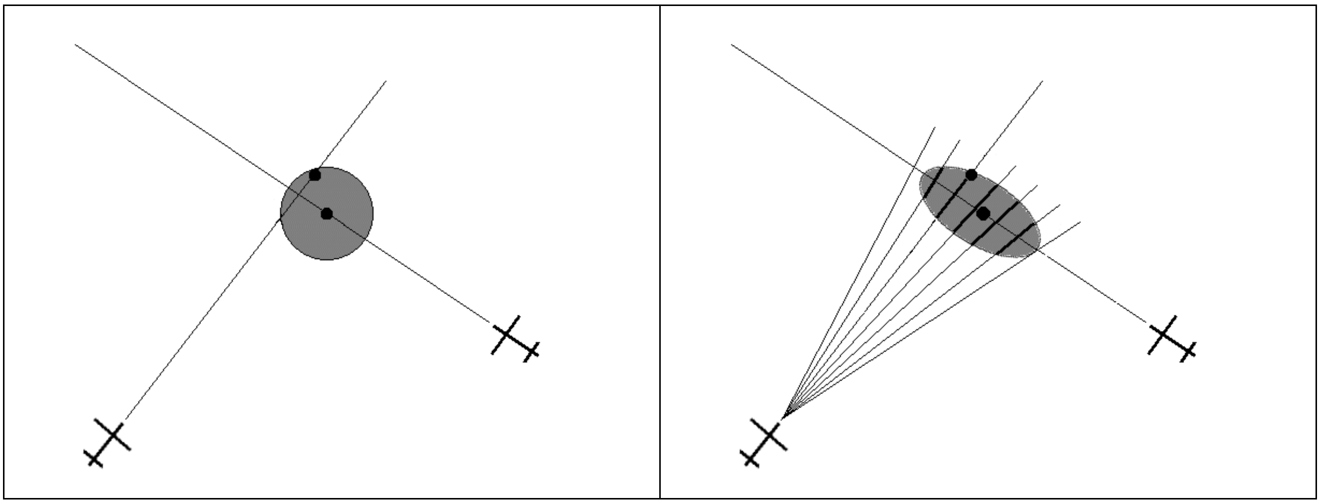
- Look ahead time: up to 20 min
- Threshold time first detection: 6 min
- Threshold time switching from priority rules to co-operative: 5 min
- ACAS time: ~30 sec

The use of intent information allowing for a longer look ahead time is preferred, but not required. Aircraft transmitting only their state information will make look ahead times of up to 20 minutes hardly feasible, and the consequence is that conflicts are detected with shorter times to conflict. So, transmitting intent will provide advantages as providing the crew with more time to react on a conflict situation, allowing for more efficient manoeuvring and from a passenger viewpoint allowing for a more comfortable manoeuvre. Moreover, for intent information to be beneficial it should improve the missed (including last minute) and nuisance alert rates, these alert rates are important because they affect safety and pilot acceptance.

Conflict detection in detail

Regarding conflict detection, two main options are available: geometric or stochastic conflict detection. The geometric method uses the actual and planned flight path while the stochastic method predicts also possible deviations of traffic from their paths aiming to integrate uncertainties.

Within MA-AFAS, a geometric conflict detection method will be used which predicts the loss of separation between two aircraft using state and intent information if available. Within this conflict detection method, again, two options have been selected: only instantaneous conflict detection based on the trajectories or with an additional calculation of no go zones based on possible resolution manoeuvres.



Conflict detection methods: instantaneous and the addition of a no go zone.

Using only the instantaneous conflict detection has the characteristic of less preview, preview has the added value of showing and thereby preventing new conflicts (or reoccurrence of conflicts) as a result of manoeuvring. For instance, when changing the heading in the instantaneous method, the circle (the alert zone of the intruder at the moment of closest point of approach is reached) will slightly move as the geometry of the conflict is changing. For the no go zone prediction method, the size of the zone is defined at the moment the conflict is detected and ideally does not change anymore. The no go zone calculation is mainly useful, in a reactive as well as planned resolution system, to preview the effects of planned manoeuvres. Does the planned manoeuvre create a new conflict with another aircraft or can it be executed safely.

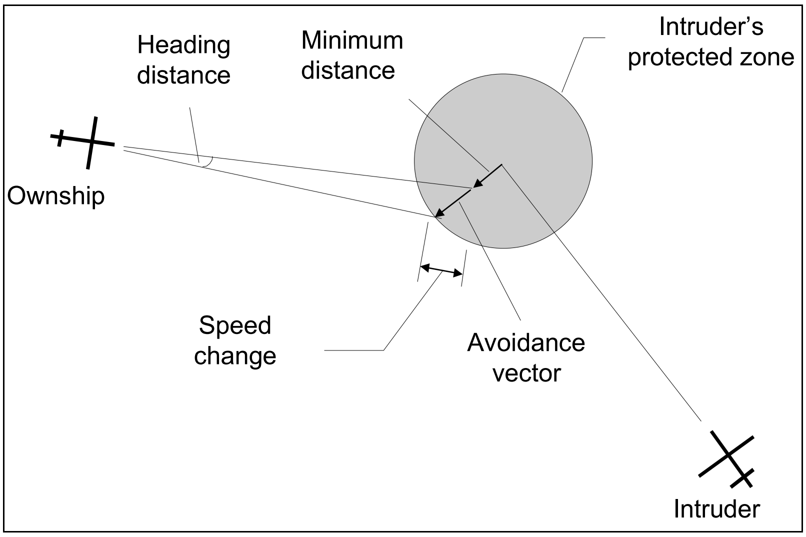
The instantaneous method calculates the position of both aircraft of the closest point of approach and a circle with radius of the separation minimum is position at the position of the closest point of approach of the intruder. The no go zone is calculated using a range of heading changes of the own aircraft from a chosen start of turn point (in the figure the current aircraft position is chosen). For each of these alternative tracks the conflict is predicted which results in a no go zone (the ellipse in the example here).

The description given is focused on the lateral situation of conflict detection, but applies also in the vertical situation.

Co-operative resolution in detail

The conflict resolution method used for the co-operative situation is the modified voltage potential resolution method. When a predicted conflict with traffic has been detected by the conflict detection module, the resolution module uses the predicted future position of both aircraft at the moment of minimum distance. The minimum distance vector is the vector from the predicted position of the intruder to the predicted position of the own aircraft. The avoidance vector is calculated as the vector starting at the future position of the own aircraft and ending at the edge of the intruder's protected zone, in the direction of the minimum distance vector. The length of the avoidance vector is the amount of intrusion of the own aircraft in the intruder's protected zone and reflects the severity of our conflict. It is also the shortest way out of the protected zone. Therefore the own aircraft should try to accomplish this displacement in the time left till the conflict. Dividing the avoidance vector by the time left yields a speed vector which should be summed to the current speed vector to determine the advised speed vector. The result is an advised track and a ground speed. Using the three-dimensional vector also an advised vertical speed is calculated.

Each resolution method has its singularities in which the avoidance vector becomes zero or the sign can not be determined. This issue will have to be investigated in depth and will require dedicated studies as it is out-of-scope for MA-AFAS.



Lateral conflict resolution geometry

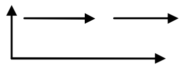
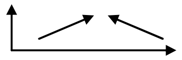
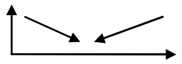
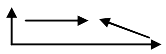
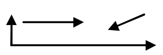
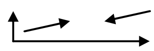
It is important to notice that the direction of the smallest change in heading, vertical speed, is the mandatory direction of movement by definition. Because both aircraft are moving, this mandatory direction of movement is essential in order to solve the conflict rather than increase the conflict situation. The two reasons for this rule are to make the need for explicit co-ordination superfluous and to shift the emphasis to safety while still considering efficiency instead of optimising efficiency while maintaining safety. The latter approach is more applicable to the priority-based resolution method acting more than 5 minutes prior to the conflict.

In the horizontal plane, the smallest change in aircraft vector would be a combination of heading change and speed change. This speed change is optional while the heading change is mandatory in case the horizontal manoeuvre is chosen.

Priority rule based resolution in detail

When a conflict has been detected, the priority is to be determined. In a pair wise encounter, one aircraft will be assigned the responsibility to solve the conflict. For this assignment of responsibility, a set of rules is used. A priority level is allocated to both aircraft involved in the conflict. The one with lowest value shall modify its trajectory to make it conflict free, the other has right of way and may stay on its original trajectory.

The set of rules are:

Conflict situation	Description	Priority
Both in level *		The closest in distance to the point of loss of separation
Both climbing*		The closest in distance to the point of loss of separation
Both descending*		The closest distance to the point of loss of separation
A in level, B climbing		A has the right of way
A in level, B descending		B has the right of way
A climbing, B descending		B has the right of way

When the priority has been determined the aircraft which has to give way has to re-plan its trajectory in such a way that it is conflict free with respect to all other known aircraft trajectories. This requires checking the re-planned trajectory against all other known aircraft intent. Apart from this requirement no other limitations apply for the resolution manoeuvre. The only requirement is to solve the conflict and not trigger any new conflict. As soon as the new trajectory is activated, it will be broadcast.

Whether the crew of the priority aircraft will be informed about the existence of the conflict is to be decided. It can be regarded as a situation which exists in the current MAS operation, as well in which a conflict is detected by the controller and one of the crew will be tasked to change its path, while the other aircraft is continuing as is without being aware that a conflict situation had occurred. Since in the autonomous operation the tasks between air and ground are changing significantly, the decision to keep the crew of the priority aircraft in the loop as monitor of the situation might be the opposite reasoning.
The main issue is that an alert should require a crew action or a preparation for an action. An alert which will not lead to any crew action should not be generated.

Transition from priority rule based to co-operative resolution
As explained earlier, the co-operative resolution method is used when the time to conflict is less than the threshold time. This can happen in two ways, first because the conflict was only detected in a relatively late stage, or secondly because the aircraft which should give way has not taken the right action. The first case should not happen frequently but on the other hand can not be considered to be remote (e.g. flying without FMS engaged due to severe weather avoidance, unwanted FMS behaviour and other unforeseen operational reasons). This leads to a situation in which both crews have less time, but still sufficient, to consider the conflict resolution. Apart from that, the situation is clear to the crew from the moment the conflict has been detected.

The second case however becomes more complex. Nominally, a conflict is detected based on intent well in advance allowing for the priority rule based resolution method. In this event, the conflict resolution has no limitations other than to solve the conflict and not to trigger any new conflict. No constraints exist in the direction of movement. However, in non-nominal situations when no action is taken and the time to conflict becomes less than the threshold time, the resolution changes from priority rule based to co-operative for which the voltage potential model is used. The latter does constrain the direction of movement: the only allowed direction of movement is in the direction which leads to the smallest change in heading or vertical speed. The moment at which the time to conflict becomes less than the threshold time, the transition from priority rule based to co-operative rule based constrains the possible resolution for the crew which had to give way initially. This change in resolution method needs to be clearly presented to the crew and is an issue for research within MA-AFAS, and also depends on the question whether or not it is mandatory to resolve conflicts more than 5 minutes in advance (worse case is the MA-AFAS selected concept of mandating action for the priority rule based method).

Conflict prevention

Conflict prevention is a function which serves as an advisory function towards the crew to indicate what they can expect when they are modifying their route. It serves as an extended conflict detection function or as a "what if" function in case the crew wants to change its flight plan.

The conflict prevention function calculates no go zones, or primary directions of movement like heading and vertical speeds in which conflict can be expected. The conflict prevention function is closely related to the conflict detection method chosen.

Calculation of no go zones or primary directions of movement is only possible by using a conflict detection module based on the current state and intent. Absolute no go areas are not predictable while these can only be predicted based on planned trajectories. So, conflict prevention may consist of:

- Indications regarding heading and vertical speed based on the current aircraft state;
- Prediction of no-go zones based on current active flight plan
- Prediction of no-go zones based on a temporary flight plan
- A combination of the two above mentioned methods.

Conflict prevention should provide feedback about conflicts while re-planning the route using the FMS either graphically or conventional by means of the CDU. When standard autopilot modes are used, also indications regarding predicted conflicts should be provided. A heading change, vertical speed change or an FMS route modification should in no case lead to an immediate conflict without prior knowledge by the crew of this conflict.

3.1.5.7 Transitions between FFAS and MAS

3.1.5.7.1 Defined Concepts

There are two transitions, which are inherently different. The first one is the *Vertical Transition*. This transition will be used when FFAS is positioned above MAS. The second one is the *Horizontal Transition*. This transition will be used when FFAS and MAS are adjacent.

Between MAS and FFAS a transition layer or zone is created which is solely reserved for aircraft which are in transition from one airspace type to the other. This transition layer or zone is introduced to avoid possible loss of separation between free flight and controlled aircraft.

3.1.5.7.2Concept of Horizontal Transition

Horizontal transitions can exist within different airspace definitions. An example of such a concept is the situation where some sectors within upper airspace will be FFAS and other sectors remain MAS. Another airspace definition could use the total airspace, except the TMA, for FFAS (see figure 1). The different airspace definitions imply different controller procedures and possibly an adapted ground HMI.

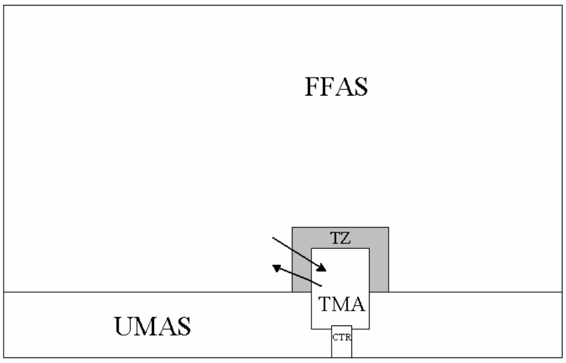


Figure 1: Total airspace defined as FFAS, except for the TMA

When the TMA is the only MAS sector surrounded by FFAS, a number of MAS entry and exit points are defined. Aircraft will cross the entry points with a published track, time constraint (if necessary), cleared speed and altitude. These entry points resemble the currently used initial approach fixes (IAFs).
All aircraft entering the TMA via the same entry point should be separated, which implies a certain sequence at the entry point. Current day arrival managers assist controllers in achieving a sequence. Future experiments could assess to what extent arrival management support tools could benefit the transitions between FFAS and MAS.

When MAS is not restricted to a TMA but is just one of the en-route sectors, the situation is slightly different because the number of entry points is less restrictive compared to the previously described situation. In addition the altitude range for which an entry point can be used is far less restrictive.

Depending on whether the MAS sector to enter is capable of free routing, the entry points can also be flexible in their position on the MAS boundary.
For both situations the entry points are located on the boundary between MAS and the transition zone. Transitions will use specific entry and exit points. In the experiment described here the nature of these points can differ depending on the route with which they are connected:
There will be separated entry and exit points, if these points are connected with a one-way route. Aircraft entering and exiting FFAS are laterally separated.
There will be combined entry and exit points, if these points are connected with a two-way route structure.
In both cases entering and exiting traffic are vertically separated.
From the results of real-time simulations at the NLR ATC Research Simulator (NARSIM) it can be concluded that one MAS exit point is not sufficient for a controller to work with. To remain the required flexibility three exit points or an exit area is needed between MAS and FFAS.

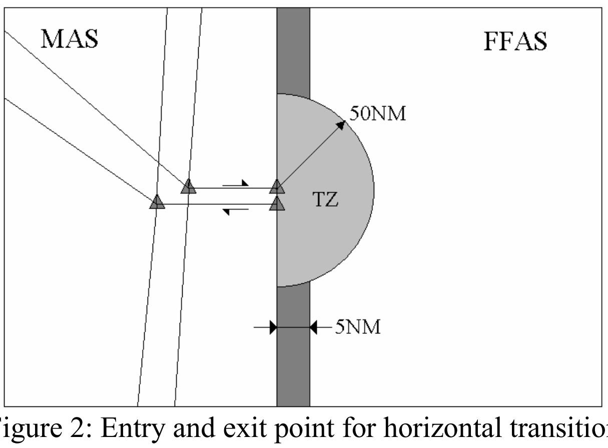


Figure 2: Entry and exit point for horizontal transition

A separation area of 5NM between MAS and FFAS is defined. This separation area is introduced to avoid possible intrusions of protected zones between free flying and controlled aircraft. It is not allowed for any aircraft to enter this separation area (see figure 2).

Around the MAS exit point, within FFAS, a circular transition zone with a 50NM radius is defined. This transition zone is introduced to prevent conflicts between MAS exiting and MAS entering aircraft close to the MAS exit point. To prevent conflicts, vertical separation is assured through flight level assignment for aircraft either entering or exiting MAS.

From the results of real-time simulations at the NLR ATC Research Simulator (NARSIM) it can be concluded that aircraft should be allowed to climb/descend within the transition zone, at own discretion, towards FFAS. While aircraft towards MAS within the transition zone, should be allowed to climb/descend, after co-ordination with the tactical or planner controller.

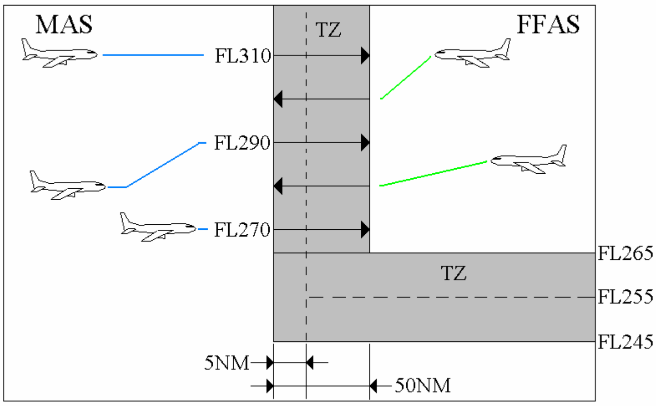


Figure 3: Vertical separation for horizontal transition

Within the concept, as shown in figure 3, the lowest FFAS entry flight level will be FL270 and the lowest MAS entry flight level will be FL280. The flight levels FL250 and FL260 shall be dedicated for vertical transitions.

3.1.5.7.2.1. MAS to FFAS horizontal transition

The tactical controller (TC) clears the aircraft to pass the MAS exit point and instructs the crew to expect free flight operation some time (about 10 minutes) before the MAS exit point will be reached. The crew then prepares to enter FFAS by switching on their ASAS (in case it was not already switched on). When passing the MAS exit point the aircraft enters the transition zone. Within this transition zone no immediate conflict should occur because the traffic in the transition zone, coming from MAS, is still separated since it was separated in MAS. Traffic coming from FFAS is separated from traffic coming from MAS by different altitude levels assigned for MAS exiting and entering traffic.

While residing in the transition zone, the crew of the aircraft intending to enter FFAS has to assure separation with traffic within the transition zone and traffic in FFAS. While residing in the transition zone only lateral manoeuvres are allowed since the level above and below are reserved for MAS entering traffic. After having entered FFAS both lateral and vertical manoeuvres are allowed.

A typical transition would look like this:

TC: instruct crew to expect free flight operation at MAS exit point;
Crew: affirm to ATC and activate ASAS function if not yet activated;
TC: assign flight level to maintain in transition zone;

Crew: affirm to ATC;
TC: hand over separation responsibility to flight crew at MAS exit point;
Crew: accept separation responsibility and continue flight via the separation zone into FFAS.

3.1.5.7.2.2 FFAS to MAS horizontal transition

Aircraft wanting to enter MAS will contact the planner controller (PC) of the MAS sector about 15-20 minutes before reaching the transition zone. The PC will assign a flight level to be reached before entering the transition zone and a required time of arrival (RTA) to be met at the MAS entry point. Since the PC planned the incoming traffic in such a way that it will be sequenced and separated when reaching the MAS entry point, the conflicts that might occur in the transition zone should be minimal. While flying in the transition zone approaching the MAS entry point, the PC will hand over the aircraft to the tactical controller (TC).

A typical transition would look like this:
Crew: contact planner ATCo to request MAS entry;
PC: assign flight level and RTA at MAS entry point;
Crew: affirm flight level and RTA;
Crew: monitors traffic in transition zone and solves conflicts if required with other inbound traffic;
PC: hands over the crew to the TC;
TC: takes over separation responsibility from the crew when passing the MAS entry point;
Crew: affirms change of responsibility and switches off ASAS function if desired.

3.1.5.7.3 Concept of Vertical Transition

The first region where Free Flight is implemented will probably be an upper airspace area, for example above flight level 245. Flying at high altitude has a clear economic advantage for cruising aircraft. Another advantage of this method is that it allows a gradual implementation of free flight by lowering the altitude limit, similar to the National Route Program in the US, making it more acceptable when introduced.

Below flight level 245 will then be managed airspace and the area between flight level 245 and 265 will be defined as the transition zone (see figure 4 and 5). This transition layer avoids predicted conflicts and possible intrusions of protected zones between free flying and controlled aircraft if no transition zone would be used.

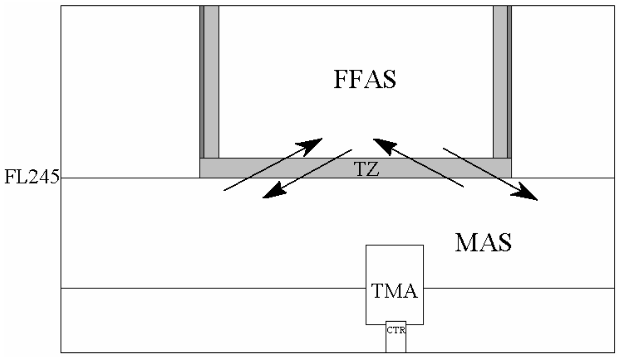


Figure 4: Airspace structure for vertical transition

3.1.5.7.3.1 MAS to FFAS vertical transition

While operating in MAS, the ASAS system is switched on to prepare the FFAS entry. The crew ensures a conflict free transition zone entry and requests ATC to leave MAS. The TC clears the aircraft into the transition zone, assuring no immediate conflict occurs after entering the zone and ASAS is operative on board.
Once the aircraft has entered the transition layer it may continue its climb on own separation responsibility using ASAS. Inside the complete transition layer the flight crew is responsible for separation assurance. Whenever the flight crew intends to climb to FFAS, the ASAS module containing conflict detection and resolution algorithms should be switched on well before entering the transition layer because as soon as the transition layer is entered, the crew is responsible for the separation assurance.

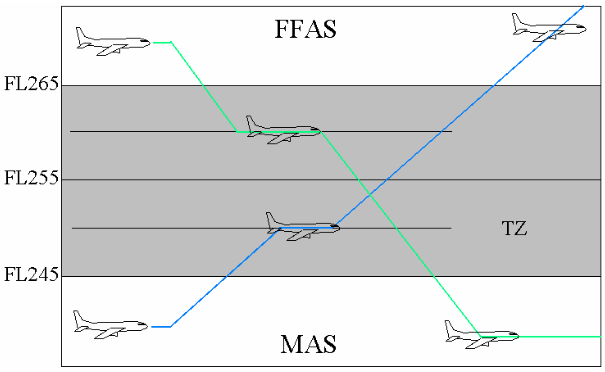


Figure 5: Use of Transition Layer for vertical transition

While still operating in MAS, the ASAS system is only switched on to prepare for FFAS operation because ATC is still responsible for separation assurance at that moment.

A typical transition would look like this:
TC: instruct crew to expect free flight operation when crossing lower transition layer level;
Crew: affirm to ATC and activates ASAS function if not yet activated;
TC: assign flight level into the transition layer;
Crew: affirm to ATC;
TC: hand over separation responsibility to flight crew when crossing the lower transition layer level;
Crew: accept separation responsibility;
Crew: monitor traffic and initiate climb out of the transition layer into FFAS.

3.1.5.7.3.2 FFAS to MAS vertical transition

The crew requests ATC to enter MAS while flying in FFAS. ATC clears the aircraft on a certain heading (or underlying airway), speed and altitude for MAS entry. Having received this clearance, the crew is allowed to descend into the transition layer coming from FFAS taking into account the constraints to enter MAS. At this moment the crew is still maintaining self-separation. Time constraints may be used for the moment or position of descent.

After entering MAS, the crew may switch off the ASAS functionality upon the crew's own discretion, in order to avoid nuisance alerts.

A typical transition would look like this:

Crew: contact planner ATCo to request MAS entry;
PC: assign constraints for MAS entry;
Crew: affirm constraints if feasible;

Crew: monitors traffic in transition layer and descents into the layer and solves conflicts if required with other inbound, but also outbound traffic;
PC: hands over the crew to the TC;
TC: clears aircraft down into MAS;
TC: takes over separation responsibility from the crew when passing the lower boundary of the transition layer;
Crew: affirms change of responsibility and switches off ASAS function is desired.

3.1.5.8 Application time constraints
Refer to the times mentioned in the previous section for:
- Look ahead time
- Threshold time first detection
- Threshold time switching from priority rules to co-operative
- ACAS time

3.1.5.8 Single transaction scenario
N/A

3.1.5.9 Overlapping transaction scenario
N/A

3.1.5.10 Non-overlapping transaction scenario
N/A

3.1.5.11 Information exchanges

Information exchanges for autonomous operation are:
- ADS-B reports for creating traffic situation onboard of each aircraft
- TIS-B for non ADS-B equipped aircraft, but this will not be considered in the scope of MA-AFAS autonomous operation application
- Aircraft to aircraft communication in support of conflict detection and/or priority determination/confirmation, but this will not be considered in the scope of MA-AFAS autonomous operation application.

The required bandwidth depends on:
- The amount of data per aircraft (see later in this section)
- The frequency of broadcasting this data (see later in this section)
- The number of aircraft within ADS-B range (ADS-B range is TBD, number of aircraft, see section 2.2)

ADS-B broadcast contains state information and if available also intent information. The update frequency required for autonomous operation will be:
- State information, every TBD (3 as a first guesstimate) seconds
- Intent, every TBD (20 as a first guesstimate) seconds and when intent has changed.

State information is defined as:
- Latitude, longitude
- Altitude and vertical speed
- Heading and track
- Airspeed and groundspeed
- Aircraft callsign and ICAO code

Intent is defined as:

- Trajectory change points (number of TCP covering up to 20 (TBD) min of trajectory) intent (FMS guided path):
- TCP lat, lon
- Altitude at TCP
- Estimated time over TCP
- Type of TCP:
- Fly over turning point, radius of turn
- Fly by turning point, radius of turn
- Level off TCP
- Start of climb/descent, target vertical speed
- Non trajectory change point intent (auto pilot settings)
- Selected heading/track
- Selected altitude
- Selected vertical speed
- Selected airspeed/Mach

State information is always available because it defines the current state vector of an aircraft. Intent information however depends on the flight mode used by the crew. In case the FMS is used for following a 4D flight path, intent by means of 4D TCP's are available, in which the 4th dimension might be ETA's and not necessarily RTA's. In case standard autopilot modes are used, non-TCP intent could be used. Combinations could also be foreseen, for example if the lateral flight path is controlled by an FMS route while the vertical profile is controlled using standard autopilot modes like altitude select or vertical speed. If TCP intent information is either not transmitted or not received from another aircraft then it will have consequences for conflict detection, in these circumstances the conflict detection is almost certainly limited to the 'threshold time first detection'. And consequently the conflict resolution will be the co-operative one.

In all cases intent information should be transmitted which describes the planned flight path best. In no case should intent information be transmitted which is not used for flight path control.

Aircraft to aircraft data exchange.

In case explicit co-ordination is required, see section 3.1.5.6, extra communication between the two conflicting aircraft will consist of:

- Aircraft ID with which a conflict has been detected
- Resolution method: priority rules or co-operative
- In case priority rules: priority situation
- In case co-operative: required direction of movement

3.1.5.12 Alerting

Autonomous operation covers conflict detection and resolution which is to be regarded as a standard operation, unlike ACAS traffic conflicts which are a safety net function. A conflict detected during autonomous operation will be accompanied by a visual as well as an aural alert, but this should be considered as standard operation and not as part of abnormal or emergency operation.

Alerting as part of the autonomous operation function will consist of the following alerts:

Event	Condition	Visual	Aural
Conflict newly detected	$T_{conflict} > T_{look\ ahead\ time}$	No	No
	$T_{conflict} > T_{threshold}$, prio	TBD	TBD
	$T_{conflict} > T_{threshold}$, no prio	Yes, alert 1	Yes, alert 1
	$T_{conflict} < T_{threshold}$	Yes, alert 2	Yes, alert 2
Conflict not solved while $T_{conflict} > T_{threshold}$	$T_{conflict} < T_{threshold}$	Yes, alert 3	Yes, alert 3

Alerting as part of ACAS is not covered in this function description.

3.1.6 Enhanced Situation Awareness

3.1.6.1. Operation Service Description

This service uses traffic information (provide either autonomously using ADS-B or by the ATC using TIS-B), which displayed to the crew on a CDTI, will enhance the crew traffic situation awareness.

The Enhanced Situation Awareness service is expected to be most effective during visual acquisition approaches. It is envisaged as an extension of the current visual traffic acquisition prior to executing an instrument approach applying visual separation on final. The flight crew uses the CDTI to identify and track the preceding aircraft more effectively, and as a result, will aid achieving a separation below the standard radar separation minima by visual means.

The application is expected to improve the safety as well as improve the routine performance of approaches maintaining visual separation. It might support reduction of the visibility requirements needed to maintain visual separation. It also is the first step towards a future application which would allow maintenance of own separation from the preceding aircraft by the crew in all weather conditions by means of the CDTI only.

This application is in line with the “Operational Concepts for Cockpit Display of Traffic Information (CDTI) Initial Applications” document of the Applications Sub-Group of RTCA Special Committee 186, Working Group 1.

3.1.6.2. Scope and Objective

Enhanced Situation Awareness is active from Take-off until Landing. Before Take-off and after Landing, the ground situation awareness will be addressed by the Taxi Management.

The aim of this application is to achieve an increased use of visual separation in order to keep an optimum flow of traffic. The key benefits are foreseen to occur within the approach phase.

3.1.6.3. Expected Benefits and Anticipated Constraints

3.1.6.3.1 Expected Benefits

Enhanced Situation Awareness will aid in the acquisition of other traffic, particularly on approach, easing some of the workload on the controller and the pilot for visual approaches. The benefit is that this supports use of visual approaches where visual approaches allow closer spacing than standard IFR separated approaches (eg spacing aircraft 3 NM on long final to get 2 NM over the threshold, in contrast to spacing 3.5 NM on long final to get 2.5 NM over the threshold during standard radar separation operations). This then gains increased runway capacity at airports, particularly for close parallel runways (such as Frankfurt).

The CDTI supports positive identification of traffic. The flight identification on the display helps to avoid confusion of different targets. In a period of high traffic load repeated positive identification of the same target is possible (as might be required after a change in relative position).

Maintaining visual separation is facilitated**.** If the target to be followed is selected and highlighted on the CDTI, the visual separation is easier to be maintained. Continuously monitoring of the separation to the traffic is possible, allowing changes in trends to be identified. Therefore, changes in speed and heading of the target are easy recognisable and may be taken into account earlier than without the Enhanced Situation Awareness. Even in marginal conditions, a continuous operation is therefore possible.

Reduction of controller workload**.** Especially when weather conditions are below optimum (ie clouds below 4000 ft AGL or a visibility of less than 10 km), the controllers are likely to experience a high workload (eg multiple traffic information RT messages) as they try to provide sufficient information to the aircrew for them to establish and maintain visual acquisition. The information provided by the CDTI replaces most of the controller call outs by providing all relevant traffic information including traffic ID, distance, relative bearing and altitude, and therefore reduces the controller workload. This is particularly useful during changing relative positions of aircraft. As a result, the only information that the controller has to issue with Enhanced Situation Awareness is the target ID and this should only need to be issued once. All other information can be obtained by the crew from the CDTI.

Reduction of pilots workload**.** Obtaining visual airborne separation is achieved in two steps. First, the target traffic has to be acquired visually, second visual contact has to be maintained. Both steps required a significant amount of the pilots attention, especially in judging relative position and speed under marginal weather conditions. Using a CDTI, all relevant information (eg traffic ID, distance, relative bearing, heading and altitude), is dynamically available all the time, so less voice communication is required to identify the traffic concerned. The CDTI also provides information of the targets ground track and speed changes, which helps to maintain the spacing, particularly on finals.

3.1.6.3.2 Anticipated Constraints

The CDTI is likely to be a small display and therefore, in high traffic densities, the display will become cluttered. Intelligent decluttering algorithms will have to be implemented in order to be able to use Enhanced Situation Awareness in these situations.

Using RT communication, the call sign of the target traffic must not be used in order to avoid the risk of the target aircraft being mislead by the communication. (This will not be the case when using point to point data link as the target aircraft will not be aware of the communication between the other aircraft and the controller). Instead, it is recommended that the flight ID be used to identify the target aircraft (eg “follow delta lima hotel 1302” instead of “ follow Lufthansa 1302”).

3.1.6.4. Human Factors

Human factors consideration mainly focus on the use of the CDTI. The aspects that need to be addressed are :

- Easy scale change
- Decluttering, both automatic or selectable
- Identification and Selection of target traffic
- Clear provision of the information on the selected target
- Identification of the currency of the data (ie whether the information on the traffic is out of date)

3.1.6.5. Operating Method Without Operation Application

Operating without Enhanced Situation Awareness will mean that visual acquisition and maintaining separation from the selected traffic will require greater interaction between the controller and the pilot. However, apart from this, there will be no effect on the types of operation that the aircraft can carry out.

The sequence of events for Visual Acquisition without Enhanced Situation Awareness is expected to be :

1. ATC give a clearance to keep a certain distance or time behind a specified target aircraft, where the target aircraft is identified by its relative position to own aircraft
2. The crew look for the target visually
3. After external visual recognition of the Target, the Aircrew reply to the ATC, confirming that they have the Target in sight
4. The pilot then starts maintaining visual separation.

3.1.6.6. Operating Method With Operation Application

No significant operational changes are required with this application as the CDTI only acts as an additional source of information. RT communications have to be extended to include the use of flight identification and operational procedures will need to be changed to allow the pilots to use the CDTI to acquire and maintain separation from a target aircraft.

The sequence for use of Enhanced Situation Awareness on approach is expected to be :

1. ATC give a clearance to keep a certain distance or time behind a specified target aircraft (where the flight ID of the aircraft is supplied in the clearance)
2. The crew look for the target using the CDTI as an aid to visual acquisition
3. After external visual recognition of the Target, the Aircrew reply to the ATC, confirming that they have the Target in sight
4. The pilot then starts maintaining visual separation.

3.1.6.7. Application Time Constraints

The display of the traffic information is time critical. It will be important that the data is kept sufficiently current to enable good correlation between the CDTI and the actual situation. It is expected that the required currency of the data will change depending upon the phase of flight. The following are some estimates of the data refresh rates required are :

Take-Off	5 seconds
Initial Climb Out	20 seconds
En route	60 seconds
Approach	15 seconds
Landing	5 seconds

3.1.6.8. Information Exchanges

ADS-B messages or TIS-B messages will be required to provide the traffic information on the CDTI. In addition, communication between the ATC and the aircraft will need to be extended to allow for traffic identification using an ident, rather than by relative position. The communication between the aircraft and the ATC could be either by voice or via data link communications (such as that provided by a CPDLC service).

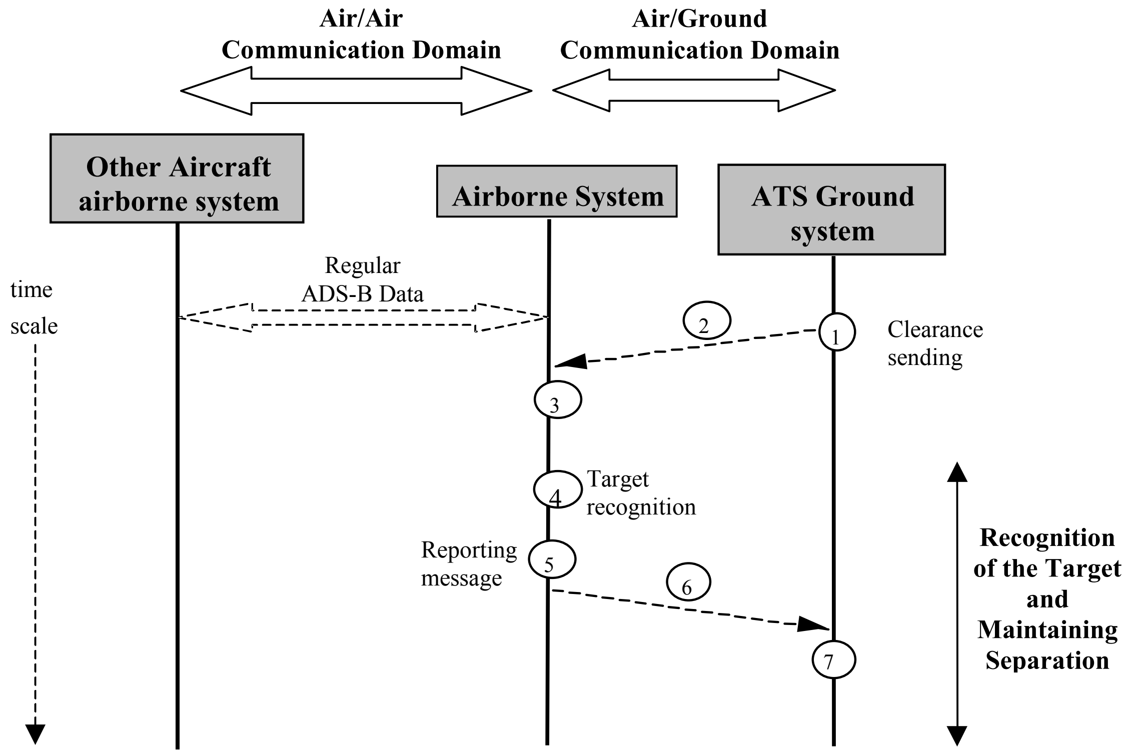


Figure 4 : Sequence diagram for Enhanced Situation Awareness

3.1.6.9. Exception Handling

In case the target information is lost from CDTI, for any reason, then Enhanced Situation Awareness cannot be used. Depending upon the visual conditions and the clearance required, the crew might have to abort their current operation (if, for example, the Enhanced Situation Awareness was being used for separation spacing on approach and the weather conditions were marginal). However, in general, it is anticipated that loss of Enhanced Situation Awareness will just increase workload on the controller and the crew as they revert back to unsupported visual acquisition.

3.2 Taxi Management Applications

The Taxi Management application foreseen to be implemented in the scope of the MA-AFAS project can be divided into 4 sub-applications: map display, ground CDTI, taxi clearance handling, and runway alert. These applications are explained in detail in the following sections.

3.2.1 Map Display

3.2.1.1. Operations Service Description

The Map Display application is an electronic replacement of the paper charts currently used by the crew to plan and conduct taxi operations. The use of an electronic display allows several enhancements of the taxi map presentation, including different scales, various map orientations, and indication of own aircraft position.

The electronic taxi charts are stored in a database and can be activated to be shown on a display in the cockpit. Various scales are available to aid the crew in both pre-taxi planning and the actual taxi operation. Position sensors (e.g. GPS) are used to determine the own aircraft's position and present this

position on the taxi map display. The crew can select different map orientations (e.g. north-up, heading-up, arc-mode) according to their information needs.
A possible enhancement of this application is the option to select certain map segments for highlighting. This allows the crew to enter a taxi clearance received via voice communication into the system for later reference.
This application is the basis for all other taxi management applications.

3.2.1.2. Scope and Objectives

Airport charts are used during several phases of flight. Prior to leaving the gate or parking position, the pilots use the charts to acquaint themselves with the airport layout, locate facilities like de-icing installations, taxi-ways, and runways, and get information about operation rules and restrictions.
Then, after push-back, and during taxiing out, the crew is referencing the chart to understand the taxi route received via voice communication and create a mental plan of the taxi route. Upon receiving additional taxi instructions, the chart may be used again to understand and plan the new taxi route.
While approaching the destination airport and after receiving ATIS information, the taxi charts are used to familiarize with the layout of the airport, to understand the implications of NOTAM information regarding the destination and to pre-plan possible taxi routes from the expected runway to the expected gate or parking position.
Right after touch-down, the crew receives the actual taxi instructions via voice communication, starting with instructions on how to exit the runway. The crew is using the taxi charts in conjunction with their outside view to follow the received taxi route.
The new application using an electronic map display does not change the principles of taxi operations but it significantly reduces the workload of pilots. Instead of flip-flopping through several pages of paper charts, the crew has an electronic map that is closer to their primary field of view and can be adjusted in scale and level of detail according to the crew's needs.
A real advantage compared to paper charts is the option to indicate the own aircraft's position on the electronic chart and even orientate and shift the map so that the current outside view is reflected on the display.

3.2.1.3. Expected Benefits and Anticipated Constraints

Expected Benefits

Most of the incidents and accidents that happen during ground operations have been caused by aircraft crews becoming disoriented and involuntarily leaving the assigned taxi route. It is often difficult for pilots to correlate the outside vision with the information presented on the paper charts, especially in low visibility conditions. The automatic indication of the aircraft's position on an electronic map is intended to increase the crew's situation awareness and therefore enhance the safety of ground operations.
Another expected benefit is the reduction in pilot workload. Instead of holding a folder with paper charts on their lap and flip-flopping through the pages while at the same time monitoring the outside situation and trying to correlate the outside view with the charts, the - pilots have all the information relevant to conduct taxi operations on the map display. This will give them more time to monitor the outside situation and conduct other important tasks.

Anticipated Constraints

The availability of precise electronic airport charts is a major concern for the realisation of this application, and – since the taxi map application is the foundation of the system – for the other applications as well. While the definition of standards for the content of such databases is under way and well advanced, the actual data acquisition and processing has only started for a few selected airports.
To avoid pilot confusion, the aircrafts' position indicated on the map display must be precise and accurate enough so that there is no discrepancy between the position shown on the chart and the actual position. Otherwise, pilots will not be able to match the situation presented to them on the display with what they see outside. Unaugmented GPS is probably not sufficient to meet this requirement, therefore the use of augmentation systems is likely to be needed. The availability of such augmentation systems is therefore a constraining factor for this and all other taxi applications.

3.2.1.4. Human Factors

The same HMI principles as used for the airborne navigation map display will be used to control the taxi chart presentation. Attention must be given to the selection of the symbology used for the taxi display, as several options exist:

- The presentation could follow the symbology and color schemes used for airborne navigation. This ensures a smooth and seamless transition from airborne to ground map display.
- To make the correlation of the outside view with the map display as easy as possible, the symbology and colour choice could be in line with what is used on the real airport surface. But even here, there is a difference between what pilots will see in daytime to what they will see during night or under low visibility.
- Following the symbology used for the paper charts can best ensure an easy transition from paper charts to the use of an electronic map.

It is likely that the actual symbology selection will be a combination of these options.

3.2.1.5. Operating Method without Operation Application

Without an electronic map display, the pilots have to carry paper charts with them that provide information about the airport layout, operation rules and restrictions, and the location of certain facilities. These charts normally consist of several pages, each providing different information with varying level of detail. These paper charts must be updated (i.e. replaced) on a regular basis to ensure that they accurately reflect the latest changes and additions.
These maps and information pages are used during the various taxi and pre-taxi phases as described in the previous sub-sections. Since the pilot steering the aircraft has to monitor the outside situation constantly, it is normally the non-flying pilot who – in addition to handling the voice communication – is looking at the paper charts, monitoring the assigned taxi route and telling the steering pilot where to go and what to look out for.

3.2.1.6. Operating Method with Operation Application

While the principle method of conducting ground operations is not altered by this application, there will be some changes to the tasks for the crew during taxiing. The use of paper charts is not obsolete with the introduction of electronic taxi maps. Paper charts will still be used to gather information about procedures and rules and will remain available in case of system failures.
The same update requirements that exist for paper charts will apply to the electronic database. However, since updating electronic information can be done more easily and faster, it is likely that update cycles will be shorter and therefore allow to present more up-to-date information to the crew.
The task of the non-flying pilot will be to adjust the electronic map display by selecting map orientation, scale, level of detail, and other options. The pilot who is steering the aircraft can use the information presented on the navigation display to enhance his awareness of the current situation. Since the navigation display is much closer to his primary field of view, he is more likely to check this display than he is to look at the paper charts.

3.2.1.7. Application Time Constraints

Unlike the en-route phase of flight, ground operations involve fast changing situations and a relatively high workload for the crew. The update rate of the information shown on the display has to reflect these demands. Any modifications pilots make to the presentation must instantly (< 0.1 seconds) change the display. The amount of time pilots are forced to look at the display to make adjustments must be kept to a minimum.

3.2.1.8. Information Exchanges

There are no changes to the information exchange between ground controllers and the crew introduced by this application.

3.2.1.9. Exception Handling

A loss of the electronic map display forces the crew to revert back to the use of paper charts, which must still be kept available.
The indication of the own aircraft's position relies on the accuracy and integrity of the position determined by the onboard navigation sensors. Any degradation of this position information must immediately be indicated to the pilot. A threshold must be defined, beyond which the indication of the own aircraft's position is automatically de-activated or marked as unreliable.

3.2.2 Ground CDTI

3.2.2.1. Operations Service Description

The Ground CDTI application will enhance the crew's awareness of the traffic situation while their aircraft is on ground.
By using provided traffic information broadcast service (TIS-B) or autonomously broadcasted position reports from other aircraft and ground vehicles (ADS-B), the current traffic situation will be displayed on top of an electronic airport map. Also included can be information about the vehicles heading and speed, its call sign or identification number, and possibly the vehicles intended path or direction.
It is likely that the symbology used for Ground CDTI will be similar to the symbology used for airborne CDTI. There will probably be a smooth and seamless transition between the airborne and the ground CDTI. The switch from the normal, airborne CDTI mode to Ground CDTI is expected to be in line with the manual switch from normal map mode to taxi map.

3.2.2.2. Scope and Objective

Ground CDTI will be used in the first phase of flight (from pre-pushback to take-off) and in the last phase (from final approach to parking). It will be especially useful in situations with limited visibility for the crew (pushback operation, bad weather), dense traffic, and complicated ground traffic patterns.
Even before asking for taxi instructions or pushback clearance, the crew will be enabled to judge the current ground traffic situation and adjust their planning accordingly. Then, during taxiing, the CDTI display will help the crew to become aware of other aircraft and vehicles in their vicinity, enabling them to enhance their mental picture of the traffic situation. By including aircraft on final approach and in take-off phase, they will also become aware of runway use and availability. Upon landing, the Ground CDTI application will again enhance the crew's situation awareness.

3.2.2.3. Expected Benefits and Anticipated Constraints

Expected Benefits

This application will increase safety during ground operations by enhancing the pilot's view of the vicinity of their aircraft. This is especially true for pushback and low visibility operation. The currently limited field of view out of the flight deck will be expanded to include areas well ahead and even behind the aircraft.
The expected increase in situation awareness will also help the crew to anticipate the traffic situation and therefore conduct ground operations more efficiently.

Anticipated Constraints

Since it is unlikely that all vehicles operating on an airport surface or even all aircraft will be equipped with ADS-B transponders, and it is evenly unlikely that any time soon a TIS-B service including all ground vehicles is available, the CDTI picture can not be expected to include all vehicles. This seriously limits the use of this application. The crew cannot rely on a display showing them that there is no object blocking their path. Therefore, Ground CDTI can only be used as an overlay system to existing observatory measures until a complete coverage is available.

3.2.2.4. Human Factors

Whereas head-down operation is normally acceptable during the en-route phase of flight, the fast changing situation during ground operations require an almost full-time head-up operation. This is especially true for approach, landing, take-off, and any low visibility operation. Therefore, the CDTI display should be as close to the primary field of view as possible and must allow pilots to gather the

information very quickly. While the use of the (M-)CDU display is not acceptable, the navigation display is likely to fulfil this requirement.
Another problem that needs to be addressed is the density of ground traffic that can easily cause severe display cluttering. Intelligent filtering should be applied to minimise this effect and provide the crew only with information essential for their manoeuvring.

3.2.2.5. Operating Method without Operation Application

The current methods for pilots to become aware of the traffic situation include:

- Looking out of the windows.
- Ground personal, assisting the crew for pushback operation and telling them about the traffic situation behind the aircraft via radio or wire link.
- Ground traffic controllers, monitoring the traffic situation and telling pilots via voice communication about other vehicles. The ground traffic controllers get their picture of the traffic situation by a combination of visual observation, ground radar, and voice position reports from aircraft and ground vehicle operators.
- Listening to voice position reports from other aircraft and ground vehicle operators.

This system relies heavily on voice reports and visual observation. This limits the capability to handle dense ground traffic, especially under adverse weather situation.

3.2.2.6. Operating Method with Operation Application

The lack of complete coverage will not allow any of the currently used methods for observing ground traffic to be replaced by Ground CDTI. Instead, this application will be used as an additional system to further enhance safety and efficiency.
It is expected that pilots and controllers can use the corresponding traffic display systems they use to reference other aircraft and vehicles more easily and unambiguously. Under low visibility conditions, the system will enable crews to follow instructions like “follow preceding aircraft” or “after landing company, line up” more promptly and accurately.

3.2.2.7. Application Time Constraints

The high density of ground traffic combined with relatively high ground speeds – especially on runways – makes position report update rates crucial for this application. In addition, any delay between the generation of a position report and displaying it on the CDTI system will cause a discrepancy between the situation observed through the window and the situation shown on the display. This would lead to more confusion instead of enhancing the crew’s situation awareness. The following thresholds are an estimate on the upper limits for these constraints:

Update rate: Objects on taxiways or runways:	min 1 sec.
Moving aircraft on apron:	min 1 sec.
Non-Moving aircraft on apron:	min 5 sec.

Total delay (time between actual position
determination and updated presentation on display): max. 1 sec.

3.2.2.8. Information Exchanges

Depending on the position reporting system used, this application will involve either ground/air (TIS-B) or air/air (ADS-B) communications (in this sense, ground vehicles are on the “air” side). The following information should be included as a minimum:

- Position (latitude and longitude, referenced to WGS84)
- Heading
- Ground Speed
- Call Sign (or other identification code for ground vehicles)

To further enhance the system, the following data could be useful:

- Assigned taxi route / runway / parking position
- Priority (e.g. emergency vehicles)
- Function / Type of vehicle/aircraft

The crew will select, which pieces of information out of this data will be presented on the taxi map display.

3.2.2.9. Exception Handling

The co-existence of conventional observation methods and CDTI ensures that there is a smooth operational transition in case the system fails or TIS-B becomes unavailable. A failure or loss of TIS-B can be determined by ground systems that then can alert aircraft of lack of service.

ADS-B failures can involve either a failure of an ADS-B transmitter in another aircraft or vehicle, or a failure of the ADS-B receiver in the own aircraft. The same limitations presented for unequipped vehicles and aircraft apply in the first case. A failure of the ADS-B receiver should be determined by means such as BITE and must be treated in the same way as a lack of TIS-B.

Any failure or lack of service must immediately be indicated to the crew. In addition, to avoid confusion caused by false or incomplete position reports, integrity checks should be done and the crew be alerted if data can not be relied on.

3.2.3 Taxi Clearances

3.2.3.1. Operations Service Description

The use of digital data-link communication (CPDLC) allows pilots and controllers to exchange messages regarding ground operation. The use of pre-defined message structures enables the direct link between the ground controllers' planning system and the taxi management display on the flight deck. Taxi instructions can be transmitted more precisely and unambiguously and can directly be shown on the taxi map.

3.2.3.2. Scope and Objective

This application will be used from pre-pushback to runway holding position and from touchdown to parking. It will be used before pushback for transferring the taxi route from the controller to the crew and exchanging requests and other messages between them. The assigned taxi route is then monitored during the taxi-out and any modifications or additions are transmitted to the system. These may include route or runway changes, hold-short-off instructions, or give-way-to instructions.

On arrival, the system will work in an equal way, providing the crew with instructions on how to exit the runway, which taxi route to take, and what parking position is assigned to them.

3.2.3.3. Expected Benefits and Anticipated Constraints

Expected Benefits

The use of digital data-link instead of voice communication will reduce the workload for both the pilot and the ground controller. Transmitted messages are stored in the system and can be displayed at any time, avoiding the need for pilots to write down any taxi instructions. Integrity checks make the need to read back these instructions obsolete, further reducing the workload on both sides. An unambiguous message format allows the data to be fed directly into an on-board taxi management system, so that the crew does not have to enter it manually. All this does not only reduce workload, it also eliminates possible misunderstandings and misinterpretations thus increasing safety.

Only an automatic transmission of a taxi route allows displaying this route on an electronic map, for there is normally no time for the crew to enter the route manually into the system, especially after touchdown. The highlighting of the cleared taxi route on an electronic taxi chart clearly enhances the crew's awareness of their assigned taxiways and any hold-off instructions or stop-bars involved. This will further enhance operation safety.

With better communication between controllers and pilots and lesser possibilities for disorientation and misunderstanding, the overall ground movement efficiency will likely be increased as well.

Anticipated Constraints

Any system that moves communication away from broadcast-type voice channels to addressed digital data-link reduces the so-called "party-line" effect. Other aircraft crews who might be affected or at least interested in conversations between a controller and a pilot will have less information to form their mental picture of the traffic situation. Other means must be provided to overcome this.
The current use of voice communication for taxi management is precisely regulated and operations depend on following these regulations very closely. Any new system intended to by-pass or replace voice communication has a significant impact on how ground movement is handled and will therefore be an issue for regulation authorities.
To be able to implement standard messages for taxi route transmission, corresponding taxi management systems must be installed both in the aircraft and on the ground. Industry standards must probably be available before someone will invest into these systems.

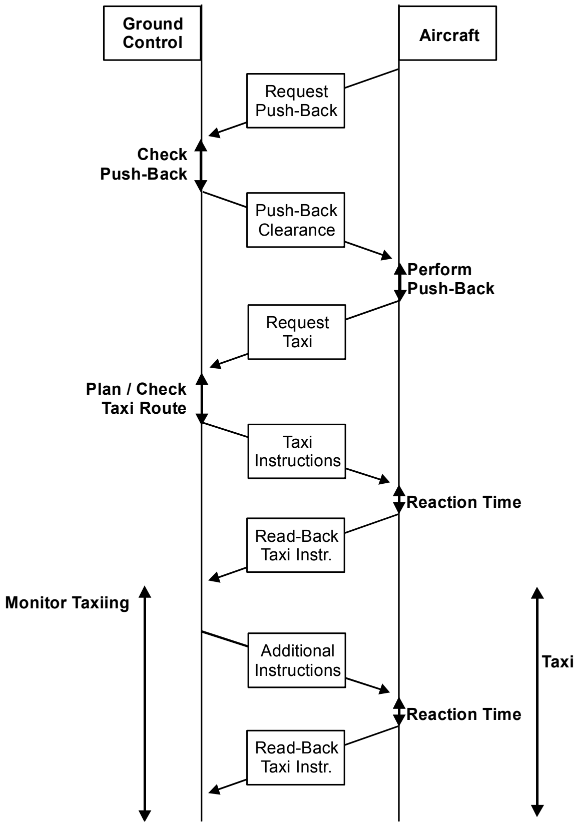
3.2.3.4. Human Factors

Clear human factors benefits are expected from this application. The current use of voice communication with standardised phrases has proven to fail in some cases, at times with catastrophic results. It is important, however, that a system intended to overcome human failure does not totally exclude the pilot. The crew should always be kept in the loop.
To enable the pilots to understand what the taxi management system is doing, all received messages should be displayed to the crew and also be stored for later review. Pilots and controllers should also have the option to use voice communication in addition to or instead of data-link at their discretion, especially for unusual and emergency situations.

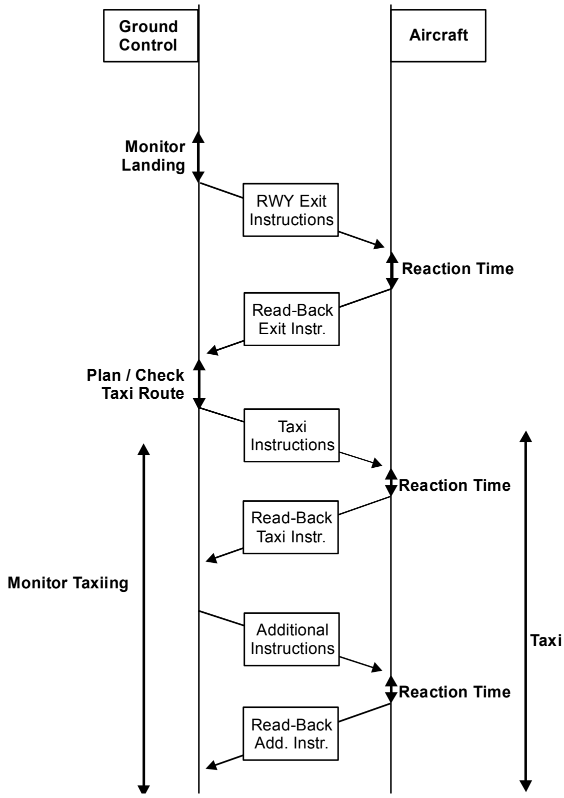
3.2.3.5. Operating Method without Operation Application

The system currently used is based on voice communication. Additional means for taxi management like controlled stop-bar lights and runway exit indicators are used on some airports. The flight deck, however, is not included in theses systems. Pilots have to record taxi instructions with paper and pen and then read back these instructions to the controller.

To follow the assigned taxi route, the crew uses paper charts as well as taxiway and runway markers and signs visible through their windows. This severely reduces the ground handling capacity of airports under bad weather conditions and often leads to confusion and disorientation. Misunderstanding often occurs whenever one part of the communication chain has problems with the English language, which is used worldwide for communication in aviation.



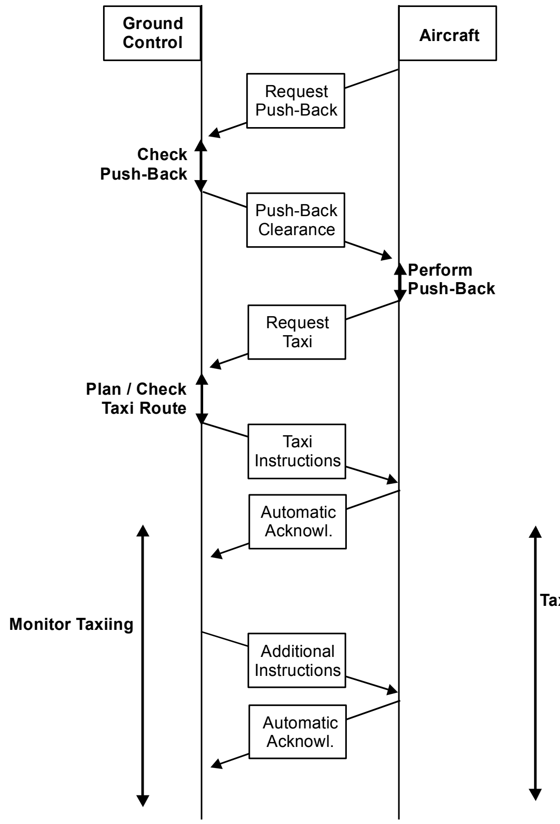
Taxi Out



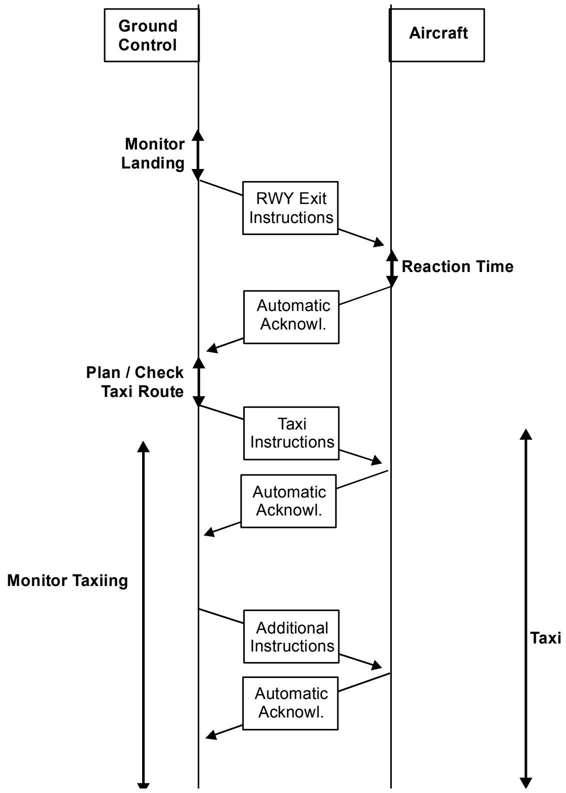
Taxi In

3.2.3.6. Operating Method with Operation Application

How the use of digital data-link for taxi clearance transmission will be integrated into the existing operation scenarios depends on yet-to-be defined regulations. It is likely, however, that both systems – voice and CPDLC – will co-exist for some time. (Voice communication is assumed to be kept available as a fallback system.) The transition will probably be gradual, with some clearances (like pushback or engine start) being used as a starting point, while messages having a more significant role in safety, like takeoff clearances, will be kept as voice messages, at least for some time.
When the transmission of taxi routes is implemented, the pilots will be shown a map of the airport with the route assigned to them highlighted. Guidance cues (like "next exit right") will help them to follow the route. In addition, they will see a textual display of any taxi related messages. Any changes to the taxi route will be shown on the map with an alert to the pilots (who are not expected to look down on the map display all the time while taxiing).



Taxi Out



Taxi In

3.2.3.7. Application Time Constraints

While strategic messages can easily be adopted with data-link communication, time-critical messages (such as "immediate stop") require more attention. For these kinds of messages, it must be assured that no delay is introduced by the system and that a priority scheme is implemented ensuring time critical messages are immediately brought to the crew's attention.

3.2.3.8. Information Exchanges

This application involves ground/air and air/ground communications. Most of them are pre-defined text phrases to handle requests and instructions. Other messages are a combination of predefined phrases and one or several data fields. For the transmission of taxi routes, a special message structure must be defined, that may include the following data:

- List of waypoints, each comprising:
    - Position (latitude and longitude)
    - Designator of taxiway or runway leading towards that waypoint
    - Attributes (such as: hold-short-off)
    - Time Constraints
- Destination waypoint (either holding position or parking position)
- Follow instructions
- Speed restrictions

3.2.3.9. Exception Handling

Any breakdown or degradation of the communication system must be brought to the attention of both the crew and the ground controller immediately. Voice communication should always be available as a fall back option.

An intense integrity check must be done on all data transmitted and received, especially if read-back procedures are to be eliminated. Both sides should be made aware of any failed or damaged transmission. Any deviation from the assigned taxi route should cause an alert to both the crew and the ground controller (advisory level).

3.2.4 Runway Alert

3.2.4.1. Operations Service Description

One of the biggest concerns regarding ground operations is the inadvertent entering of a runway while taxiing. Among the reasons for this to happen are: disorientation, disobeying hold-short-off instructions, and misinterpretation or misunderstanding of taxi instructions. While several ground-based systems are used on some airports (like ground surveillance radar and illuminated stop bars), runway incursions are still a major concern.

With an on-board electronic taxi map and the knowledge of the aircraft's position on the airport, an autonomous system can be realised that alerts the crew whenever they are about to enter a runway. In conjunction with the taxi clearance application, the alert generation can automatically be suppressed if the controller has cleared the entering or crossing of that runway.

In the scope of MA-AFAS, alerts generated by this application are restricted to an advisory level. The generation of caution or warning alarms is not foreseen in this project.

3.2.4.2. Scope and Objective

This application is confined to those phases of flight when the aircraft is either taxiing from gate to takeoff or from landing to gate. It is a pure safety function that has no influence on how the aircraft is operated.

3.2.4.3. Expected Benefits and Anticipated Constraints

Expected Benefits

Runway incursions are among the most serious concerns regarding aviation safety. There have been several cases where catastrophic events were only narrowly avoided, while in some cases fatal accidents have resulted.

In almost all of these incidents, the pilots were unaware that they had entered a runway. Most often they became disoriented in bad weather, being unable to match their outside view with the paper charts. While an electronic map on its own already helps to avoid confusion and loss of orientation, it is unlikely that pilots will look on the display all the time while taxiing. Therefore, raising an alert whenever a runway is entered will ensure that the crew knows about them doing so.

Anticipated Constraints

As with any alerting system, two issues are a concern: false or nuisance alerts and failure to raise an alert. While it is only a technical issue to make sure that an alert is raised whenever necessary, it is an operational issue to determine when not to raise an alert.

Pilots must obviously be able to suppress the generation of alerts when they enter the runway intentionally. It may be difficult, however, to make sure that pilots are made aware of entering the runway and at the same time avoid them becoming upset with the alert generation.

3.2.4.4. Human Factors
It is crucial that whenever an alert is raised, the crew is informed about the reason for the alert. Therefore, the situation causing the alert should be explained graphically on the map display. The runway that the aircraft is about to enter should be highlighted.

3.2.4.5. Operating Method without Operation Application
Without the on-board runway alerting system, these incidents can only be avoided by means of ground systems. Several airports have installed ground surveillance radars, some with warning systems that will detect runway incursions and alert controllers. The controller then has to understand the situation and call the crew that is about to enter the runway without authorisation. Precious time is often lost before the pilots are alarmed.
Most airports, however, have no runway incursion warning systems. A lot of them are not even equipped with ground radar, so that runway incursions are often undetectable, especially under adverse weather conditions.

3.2.4.6. Operating Method with Operation Application
Ground operations are not altered by this application. The increased safety margin, however, is expected to decrease the stress level for the pilots allowing them to conduct other tasks more thoroughly.

3.2.4.7. Application Time Constraints
To allow the crew to react in time before the aircraft actually enters the runway (better: the runway protection zone), the alert must be raised some time before, allowing for reaction time and the time necessary to bring the aircraft to a stop.

3.2.4.8. Information Exchanges
While it would be possible to include an information exchange so that controllers are made aware of an imminent runway incursion, or that pilots are directly informed about a warning generated by a ground-based warning system, such exchange is not within the scope of the MA-AFAS taxi management application.

3.2.4.9. Exception Handling
In case of system malfunctioning, the system will either fail to raise an alert or generate false alerts. While there is no way to detect the first, the crew should be able to quickly suppress any false alerts. In addition, the crew should be able to de-activate the system upon detected failures.

3.3 4D applications

Definitions:

Constraint Point	A fixed point in 3D space with an optional time provided by the Flight Plan, published procedures, or during negotiation by the pilot or controller. A clearance can be given to a Constraint Point
Trajectory Change Point	A fixed point in 4D (3D space and time) generated from the Constraint Points modified by the aircraft systems to add flight phase information. A clearance can be given to a Trajectory Change Point
Trajectory Point	A fixed point in 4D generated from the Trajectory Change Points modified by the aircraft systems to add meteorological optimisation and detailed turning information. A clearance cannot be given to a Trajectory Point

3.3.1 Trajectory Navigation

3.3.1.1. Operation Service Description

Trajectory Navigation provides 4D trajectory (ie 3D position plus time) generation and guidance (including LNAV, VNAV and RTA) functions, from take-off to landing. It optimises the trajectory to meet time constraints whilst minimising fuel consumption.

The Trajectory Navigation function uses accurate aircraft state information, aircraft performance information, predefined ideal aircraft profile and forecast meteorological data in order to obtain the best trajectory for the aircraft through the given constraints. The constraints are the limits placed on the trajectory where they are provided by one or more of the following :

- AOC,
- pilot,
- automatic separation assurance with another aircraft (during partial or full delegation)
- ATC
- published navigation procedures (including Airways, SIDS, STARs and APPs).

The Trajectory Navigation function comprises 4 main parts :

- Constraints Handler
- Trajectory Generator
- 4D Guidance
- Trajectory Monitor

The Constraints Handler assembles the constraints from the different sources (ATC, AOC, Crew, Other Traffic), and if available, information on significant weather, and generates a list of valid, self consistent constraints.

The Trajectory Generator uses the aircraft performance information, optimum profile and phase of flight information, meteorological forecast, aircraft state and constraints list (provided by the Constraints Handler) from which to determine the optimum trajectory for the aircraft including fuel status at each trajectory point.

The 4D Guidance function takes the crew selected 4D Trajectory and generates autopilot and autothrottle commands, taking into consideration the aircraft performance and the meteorological conditions. These commands are then used to automatically guide the aircraft to follow the trajectory whilst the AFCS is in FMS Mode.

The Trajectory Monitor uses current aircraft state and predicts ahead, a predefined time, to determine whether the aircraft will be outside a certain boundary (determined from RNP, RVNP, RTNP) from the trajectory. The predefined time is such that before missing the next constraint, the trajectory can be regenerated, re-negotiated with ATC, and activated by the pilot. If it is predicted to be outside the boundary, then the trajectory is regenerated. If a new trajectory can not be regenerated (ie no trajectory can be calculated that meets all the constraints and stays within the already cleared boundary), then this is flagged to the crew and the ATC. However, if the trajectory can be regenerated successfully, then this is automatically used as the new trajectory (ie the displays indicate use of the new trajectory but the crew are not required to activate it).

3.3.1.2. Scope and Objective

This application will be used from Take-off to Landing, although it will only have the integrity for limited use as an automatic landing system. It is envisaged that the system will be disengaged, by the crew, at the APV I/II Decision Altitude, at the latest, where it is expected hat the aircraft will already be established on the Final Approach Track and glideslope.

The Trajectory Navigation function will be active from aircraft power up to enable crew planning of the trajectory and negotiation of this trajectory where supported by the ATC. Throughout the flight, it will allow the crew to carry out what if scenarios as well as keeping them informed of their progress along the planned trajectory. After landing, the Trajectory Navigation function will not be used

3.3.1.3. Expected Benefits and Anticipated Constraints

3.3.1.3.1 Expected Benefits

It is expected that the Trajectory Navigation function will provide more accurate, optimum trajectories, with a higher precision of automatic guidance than is currently provided by 3D (non-GNSS) FMS today. Optimised trajectories will allow aircraft to attain their ETAs with a higher degree of precision and incorporating more detailed meteorological information and improving sequencing should improve fuel efficiency and accuracy of fuel consumption prediction. In the future, the greater time accuracy could be used to improve sequencing of aircraft, which would lead to an improvement in capacity.

There is no dependency on other aircraft fit or ATC capability in order to attain some benefits. However, the better the ATC can model the aircraft performance, the better the constraints that the ATC will provide and so the closer the trajectory can be to the optimum for the aircraft.

3.3.1.3.2 Anticipated Constraints

Good meteorological data is essential in order to obtain accurate predictions and so reach the agreed points within the required times and with maximum fuel remaining.

A detailed knowledge of the performance capability of the aircraft is required to gain best performance modelling for the aircraft. The performance information is available to aircraft manufacturers but some times this information is not passed on to airlines who lease or do not buy their aircraft direct from the manufacturers. Also, performance of the aircraft changes over the life of the aircraft. The performance parameters, stored within the Trajectory Navigation function should then be updated, at regular intervals, to represent the change in performance.

The constraints provided to the Trajectory Navigation function must be only positive (ie must do) and not negative (ie must avoid). Any systems that need to specify areas to avoid (such as Conflict Detection) can only do so by identifying where the route should go to avoid the area. This is potentially limiting as the specifying system must make a judgement on the best way around the area to avoid. However, this can be partially mitigated by making the system request several trajectories from the Trajectory Navigation function, using several different constraints that provide a variety of different ways around the area and doing a comparison of the trajectories to determine the best one. With this approach, the performance requirements for the Trajectory Generation function to provide this information within a sensible time would have to be investigated.

No terrain information is taken into account directly during any stage of 4D Trajectory Navigation. Some terrain information is implied by the use of predefined procedures, as these procedures have been defined to maintain safe terrain clearance. If a significant number of low level operations (such as those often carried out by helicopter operations) were required, then terrain information would need to be taken into account.

Ensuring that the crew maintain good situational awareness of what the aircraft is doing, in particular with respect to the Trajectory Navigation function, will be essential. It is foreseen that this could prove difficult due to the lack of HMI devices and the limited amount of display surface available to represent the 4D information. Also, mechanisms for easily interacting with this information will be important, which will require changes to conventional approaches to that used by today's 3D FMS.

3.3.1.4. Human Factors

The Trajectory Navigation function requires a significant amount of interaction with the crew. Firstly, the crew need to gain a good mental picture of the trajectory being proposed by the Trajectory Navigation function. They then need to be able to assess this trajectory and once they agree with it, they need to be able to monitor progress along the trajectory. They also require timely notification of a prediction, from the Trajectory Monitor, that the aircraft will not be able to continue to guide to the trajectory. Finally, the crew need to be able to edit the route and try out what if scenarios by entering waypoints and/or constraints (altitudes, RTAs, speeds).

Strategic guidance is controlled via the FMS, with the pilot selecting LNAV, VNAV, and AT on the glareshield Mode Control Panel (MCP). Tactical operation, however, can be performed in 2 ways in the MA-AFAS system: via the MCDU-FMS or via the MCP-Autopilot, allowing investigation of the HMI impacts to be performed. When tactical commands are received by voice, these will normally be entered by the crew into the MCP (as in current procedures) and will be guided by the autopilot, but when tactical commands are received by datalink, they will be automatically entered into the FMS and normally, when accepted by the crew, will be applied by the FMS (and the crew will usually also enter these as a back-up on the MCP but this need not be done immediately and the FMS will not be disengaged unless a problem occurs in the FMS). However, for delegated authority manoeuvres it is expected that both voice and data link commands will use the FMS manoeuvre planning capabilities and therefore voice commands will need to be entered by the crew.

3.3.1.5. Operating Method Without Operation Application

Currently operation in aircraft with an older FMS without a Trajectory Navigation function comprises the following sequence :

1. The crew receive the forecast meteorological information and the flight plan from the AOC in paper form.
2. The crew, during pre-flight, load the flight plan into (or select the pre-loaded company route from) the FMS.
3. The FMS generates a lateral route for the flight plan with limited profile information
4. The crew review the FMS generated route and if required, modify it.
5. Once happy with the route and when it has been cleared by ATC, the crew execute it within the FMS
6. The crew engage FMS mode on the AFCS control panel to allow the FMS to guide the aircraft (through the autopilot)

The FMS provides limited automatic guidance to the flight plan, with crude time and fuel estimates based on current aircraft state. It carries out waypoint steering, taking into account the current wind, current phase of flight and basic knowledge of the aircraft performance.

No account of the forecast weather is taken by the FMS. For significant weather to be avoided, the crew must directly enter route modifications to the flight plan.

Recent FMS may already provide some limited LNAV and VNAV functions over part of the flight plan, with varying levels of flight optimisation.

3.3.1.6. Operating Method With Operation Application

The proposed operation method with the Trajectory Navigation function is :

1. Crew are supplied with the forecast meteorological conditions and the flight plan electronically (either by portable data cartridge or via gatelink), in addition to the paper form, by the AOC.
2. The crew load this into the FMS during pre-flight
3. The FMS generates a 4D trajectory that meets the flight plan
4. The crew review the 4D trajectory produced by the FMS and if required, modify it.

5. Once happy with the trajectory and when it has been cleared by ATC, the crew activate it within the FMS
6. The crew engage FMS mode on the AFCS control panel to allow the FMS to guide the aircraft (through the autopilot and the autothrottle)

In addition to the cost index, the Trajectory Navigation function has user selectable phases of flight for the aircraft and a user definable ideal profile for the phase table. It is expected that these will be customised by the airline for its prefered style of operation. It is not expected that the crew will alter them.

The Trajectory Navigation function requires more detailed knowledge of the aircraft performance in order to obtain the best trajectories. This data will be loaded during one of the maintenance cycles, at a relatively infrequent basis (eg once every 6 months).

All time and fuel predictions will be based on the current aircraft state and the knowledge of the planned trajectory (which includes aircraft performance information and the forecast meteorological information). Therefore, the accuracy of these estimates will be significantly better.

The 4D Guidance can be disengaged at any time, for instance due to receipt of tactical commands. However, the Trajectory Generator and Trajectory Monitor functions will continue to execute, giving monitoring information on the current aircraft state with respect to the active trajectory (assuming that there was an active trajectory present at the time that the guidance was disengaged). During the period when the guidance is disengaged, the Trajectory will continued to be modified, when necessary, to try to maintain any clearance and the crew and ATC will be flagged if this clearance is exceeded. Re-engaging of the guidance will immediately resume automatic control of the aircraft, unless the aircraft is now outside the previous strategic clearance. In this case, a new trajectory will have to be generated and agreed by the crew, and the ATC (if in MAS), before 4D guidance can recommence.

3.3.1.7. Application Time Constraints

All the Trajectory Navigation functions are time critical. The Constraint Handler and Trajectory Generation functions are time critical due to the need to give a timely response to the flight crew and to be able regenerate a trajectory before the aircraft breaches the ATC clearance. The 4D Guidance and the Trajectory Monitor are time critical, due to the closed loop nature of the calculations.

The performance targets for the systems are :-

Trajectory Generation (*)	2 seconds typically, 5 seconds maximum
4D Guidance	0.5 seconds
Trajectory Monitor	30 seconds

(* - Trajectory Generation consists of the series activities Constraints Handler followed by Trajectory Generator.)
However, all constraints on meeting these timings are internal to the system.

3.3.1.8. Information Exchanges

No data link communication is required for Trajectory Navigation. However, data entry of waypoints and constraints (altitudes, RTAs, speeds) , route identifier, SIDS, STARS, and APPS from AOC or ATC could be attained by using data link. Forecast meteorological data could also be provided via a data link, such as gate link or loaded during pre-flight from some form of data loader.

The constraint information would include :-

Longitude
Latitude
Waypoint Identifier
Place Bearing Distance

Place Bearing Place Bearing
Position Tolerance (laterally only) (RNP)
Altitude Window (optional)
Time Window (optional)
Speed Window (optional)
Turn Direction and Type (optional)
Clearance

Forecast Meteorological data would include :-
Pressure
Temperature
Wind Direction
Wind Speed

3.3.1.9. Exception Handling

The Trajectory Navigation function is not safety critical although its failure will affect the flight. To overcome this during in-service operation, more than one FMS will be fitted to the aircraft. Therefore, if one instance failures (which can not be rectified by resetting the hardware) then the Trajectory Navigation function within the other FMS can be used. For this hand over to be smooth, inter-FMS communication will be required. (It should be noted that during MA-AFAS trials, this will not be the case, as only one FMS is expected to be fitted to each trials aircraft.)

All HMI devices are as a minimum duplicated within the cockpit and therefore, there will always be a secondary reversionary mode if one fails.

If a data link is used and fails, then data entry can be achieved manually, where the information can be transmitted to the crew, either by another data link or verbally, and then entered directly into the FMS.

3.3.1.10 Additional Operation Information

3.3.1.10.1 Operation within Airspace Types

For the crew to obtain most support from the Trajectory Navigation function, it needs to be versatile and easy to use under all conditions of flight. The following sections give a brief outline of the types of airspace within which the Trajectory Navigation function is likely to operate under and in what manner it is expected to operate.

3.3.1.10.1.1 During MAS

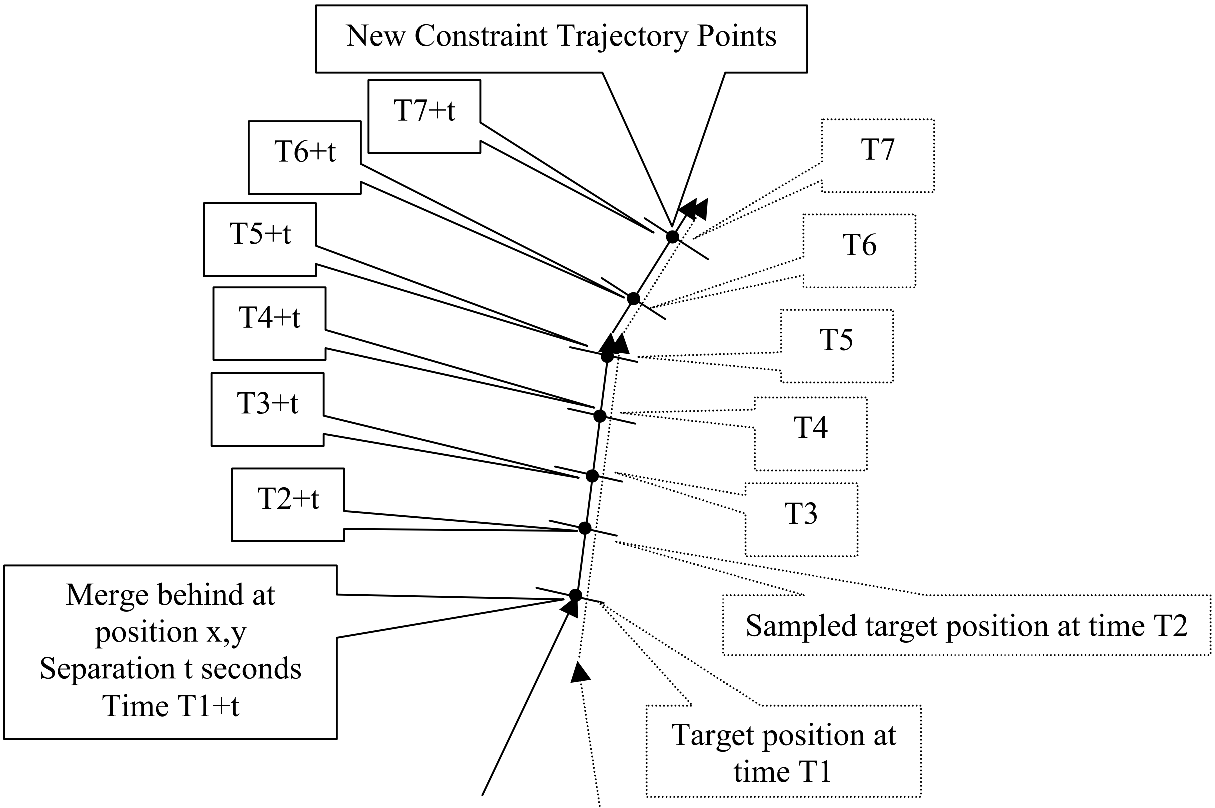
During MAS, there is expected to be 3 main modes of operation :

- Under Strategic Conditions
- Under Tactical Conditions
- Under Partial Delegation

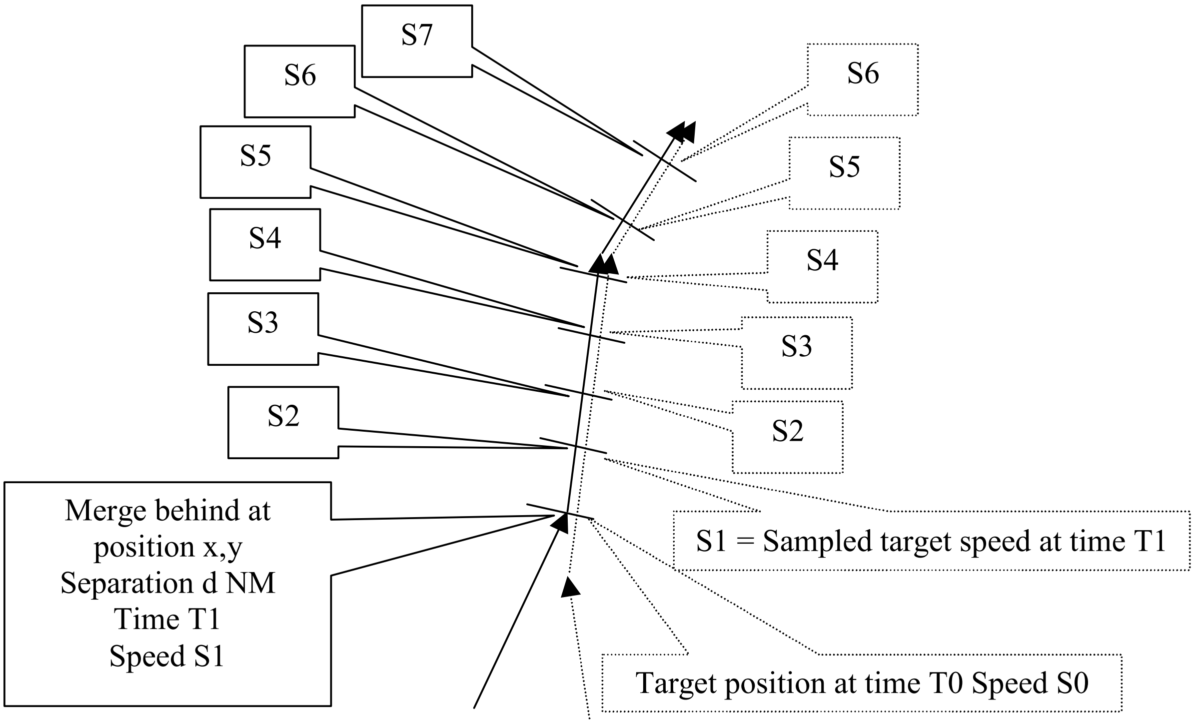
Within the Strategic mode, it is expected that the ATC has given a clearance to the crew for a significant portion of the trajectory. The system is then able to guide to this trajectory, up until the end of the clearance, continually checking that it is remaining within an allowed tolerance from the cleared trajectory. Note that if the aircraft passes the end of the strategic clearance without further clearance being obtained, the FMS will continue to fly the last downlinked trajectory while the problem is resolved by the pilot and ATC.

Under Tactical conditions (ie where the ATC has given an open ended command), the system is able to control the AFCS to carry out the command, but the trajectory generator is unable to predict where the aircraft will be as the ATC command has no defined end point. In order to give the crew some awareness of how this command is affecting their proposed flight, the Trajectory Navigation function will provide distance from next Trajectory Waypoint information (assuming that there was an active trajectory before the Tactical command was received), showing the effect on the estimated times and fuel requirements.

Under Partial Delegation, the ATC has passed some responsibility for separation from an identified target to the aircraft, for example, to carry out station keeping from an identified aircraft. In this situation, the Trajectory Navigation function carries out a monitoring role (as for Tactical conditions) but also generates a short trajectory based on the ADS-B (or TIS-B if ADS-B information is not available) information from the target aircraft. The aircraft is then guided to the short trajectory, whilst the crew are given information on the status of the aircraft with respect to their previously active trajectory (assuming that there was an active trajectory available before the Partial delegation command was received). In the case where the Partial Delegation only covers station keeping in less than 3 dimensions (ie only speed control is delegated) then the active trajectory at the time of receiving the Partial Delegation command will be used to provide the other dimensions. Any route discontinuities caused by this will be flagged to the crew to resolve.
The following is an example of time separation Station Keeping, showing the dynamic inclusion of new constraints to form a short trajectory along the existing active trajectory:



The following is an example of distance separation Station Keeping:



Sampled speeds S1..Sn also need to be modified to ensure separation d before being used by the following aircraft. No additional trajectory points are used as SPEED is flown closed loop along the existing active trajectory.

3.3.1.10.1.2 During FFAS (ie Full Delegation)

Under FFAS, the Trajectory Navigation, once supplied with any AOC and/or crew constraints for the FFAS, will provide full trajectory generation and guidance functionality. In addition, it is expected (assuming that there is sufficient time for the information to be fed to the Trajectory Navigation function) that any aircraft that conflict with the planned trajectory and which have the same or greater priority will be used to generate constraints that avoid the conflict (noting that these are positive, so the ASAS function must already have identified how to avoid the conflict). A revised trajectory will then be generated, which the crew will review and activate, allowing the Trajectory Navigation function to then automatically guide the aircraft around the conflict.

3.3.1.10.1.3 During UMAS

It is expected that operation of the Trajectory Navigation function within UMAS will be as that for FFAS. The only difference is that knowledge of other aircraft will not be guaranteed as for FFAS. This has no direct effect on the Trajectory Navigation function, although it has a significant operational effect as the crew cannot rely on the system having a complete knowledge of the traffic situation.

3.3.1.10.2 Operation at Mode Transitions

Due to the type of control that the aircraft can be under, based on airspace type as well as ATC command type, the Trajectory Navigation function must cater for the transitions. The following sections give a brief operational description of the type of actions that the Trajectory Navigation function will carry out during the transitions.

3.3.1.10.2.1 Tactical Requests During Strategic Operation

The long term goal is to complete flights completely under negotiated strategic control, but this will be impossible during ground equipment transition stages and also under exception conditions even when ground infrastructure changes are complete.

This will result in a mix of totally (4D) strategic clearances, totally (4D) tactical clearances, and mixed strategic and tactical clearances (nD and [4-n]D).

This section describes operation in mixed modes: how they are entered and how they are exited.
It concentrates on performing the transitions via the FMS interface, which is the preferred method, although it is also possible to use the glare shield Mode Control Panel (MCP) to select specific functions manually, using the autopilot directly.
When this happens, the FMS detects the mode change and mimics the change with its own internal modes (so, for instance, if the crew select HDG/TRK on the MCP, the FMS also switches from internal state LNAV to LTAC and accepts the dialled HDG/TRK value as its heading/track source, with consequences on other degrees of freedom as described in the lateral tactical control section).
When the crew select the FMS mode again, the FMS performs mode transitions as though the tactical mode had been flown via the FMS, as described in the following sections (and in the example, the FMS internal mode would revert from LTAC to LNAV and all associated flags and trajectory generations and re-negotiations would be performed as described).
All communications are assumed to be via datalink unless stated otherwise. If voice is used instead, then the crew need to perform additional steps to enter data manually.

3.3.1.10.2.1.1 Speed

1. Initial state: FMS - Full Strategic Mode (4D Trajectory Active; Automatic Guidance)
   Displays show 4D mode flags
   MCP - FMS Mode (LNAV engaged; VNAV engaged; AT engaged).
2. ATC requests speed X kt.
3. “MSG” annunciation and advisory alert inform crew that a tactical request has been received.
4. Pilot checks message, normally has no problem, and presses ACCEPT key (other option is REJECT).
5. FMS sends WILCO to ATC, switches its AT control to STAC mode (internal FMS tactical mode, MCP settings do not change), and sets 3D+STAC mode flags on displays.
6. FMS continues with 3D strategic control (3D Trajectory Active; LNAV plus VNAV). Fuel status and ETA effects are continuously updated for monitoring and display.
7. FMS monitors previously cleared 4D trajectory and alerts crew if constraints can no longer be met. Progress along the active trajectory continues to be displayed, with an indication of time deviation. The alert is given when the aircraft is within TBD minutes of the constraint that cannot be met. The alert ensures that the crew are aware that a trajectory re-negotiation process is required before full 4D strategic guidance can be selected again.
8. When ATC wishes to end the tactical speed command, they request RESUME OWN NAVIGATION (or similar). (i)
9. “MSG” annunciation and advisory alert inform crew that the end of tactical command has been received.
10. If the FMS can still meet all constraints and RTAs without significant cost, it presents the pilot with the message, a regenerated trajectory (using existing constraints plus any received with the end tactical control message from ATC), and ACCEPT/ REJECT options. The pilot normally chooses ACCEPT, resulting in the FMS sending WILCO to ATC, activating the new trajectory, switching its AT control back to 4D mode, and displaying 4D mode flags. This returns the system to the initial condition, but with a revised trajectory.
11. If the FMS can no longer meet all RTAs (ii), or if there is significant cost in meeting the existing constraints, it presents the pilot with the message, regenerates a trajectory based on optimum cost RTAs plus any constraints received with the end tactical control message from ATC, flags the relevant part(s) of the new trajectory as RTA NOT CLEARED, and presents the pilot with (ACCEPT + NEGOTIATE)/(CONTINUE TACTICAL + NEGOTIATE) options. The pilot normally chooses (ACCEPT + NEGOTIATE) (iii), resulting in the FMS sending a COTRAC

initiation request to ATC, activating the new trajectory, switching its AT control back to 4D mode, and displaying 4D and NEGOTIATING mode flags, together with the RTA NOT CLEARED flag if the current part of the trajectory is not cleared. This returns the system to the initial condition, but with a revised trajectory that may or may not be superseded by the following negotiation process.

Note (i) Another scenario for returning to 4D strategic control is that the ATC could initiate a re-negotiation of the 4D trajectory, ending with delivery of a cleared trajectory, instead requesting RESUME OWN NAVIGATION.
Note (ii) Even though the 4D clearance may have been lost, the aircraft continues to fly on the cleared 3D trajectory – it is only the RTAs that need to be re-negotiated.
Note (iii) Selecting the (CONTINUE TACTICAL + NEGOTIATE) option would have resulted in the FMS continuing on the 3D route whilst maintaining tactical speed X kt while the re-negotiation takes place.

3.3.1.10.2.1.2 Heading

This mode differs from the speed tactical command because it is not sensible to try to maintain all speed and vertical rates relevant to the active trajectory. The active trajectory will be used to provide the VNAV profile only to complete any vertical manoeuvre currently taking place.
Therefore the vertical speed will be held at that of the current active trajectory and follow any vertical rate changes until the aircraft reaches the altitude where the trajectory would have levelled out, at which point the vertical rate will latch at zero. The speed will be set to the value associated with the vertical rate in the trajectory and latch at the target value where the aircraft levels out. (i)

1. Initial state: FMS - Full Strategic Mode (4D Trajectory Active; Automatic Guidance)
   Displays show 4D mode flags
   MCP - FMS Mode (LNAV engaged; VNAV engaged; AT engaged).
2. ATC requests heading Y deg.
3. "MSG" annunciation and advisory alert inform crew that a tactical request has been received and that a terrain check is being computed.
4. To perform the terrain check, the FMS generates a new trajectory based on the new heading but including any current existing vertical manoeuvres, and checks these against the stored MORA database for conflict. (ii)
5. The crew is presented with the message and the result of the terrain check, which the pilot checks, normally has no problem, and presses ACCEPT key (other option is REJECT).
6. FMS sends WILCO to ATC, switches its LNAV control to HTAC mode, (internal FMS tactical mode, MCP settings do not change), and sets VNAV+SPD+HTAC mode flags on displays.
7. When any active vertical maneuver is complete, the FMS sets VSUS+SSUS+HTAC flags on displays (iii).
8. FMS continues in VSUS+SSUS+HTAC mode unless the crew performs further inputs. Fuel status and ETA effects are continuously updated for monitoring and display.
9. FMS monitors previously cleared 4D trajectory and alerts crew if constraints can no longer be met. Progress along the previous trajectory continues to be displayed, with an indication of time deviation. The alert is given when the aircraft is within TBD minutes of the constraint that cannot be met. The alert ensures that the crew are aware that a trajectory re-negotiation process is required before full 4D strategic guidance can be selected again.
10. When ATC wishes to end the tactical heading command, they request RESUME OWN NAVIGATION (or similar). (iv)

11. "MSG" annunciation and advisory alert inform crew that the end of tactical command has been received.
12. If the FMS can still meet all constraints and RTAs without significant cost, it presents the pilot with the message, a regenerated trajectory (using existing constraints plus any received with the end tactical control message from ATC), and ACCEPT/ REJECT options. The pilot normally chooses ACCEPT, resulting in the FMS sending WILCO to ATC, activating the new trajectory, switching its VNAV, LNAV, and AT control back to 4D mode, and displaying 4D mode flags. This returns the system to the initial condition, but with a revised trajectory.
13. If the FMS can no longer meet all RTAs, or if there is significant cost in meeting the existing constraints, it presents the pilot with the message, regenerates a trajectory based on optimum cost RTAs plus any constraints received with the end tactical control message from ATC, flags the relevant part(s) of the new trajectory as NOT CLEARED (iv), and presents the pilot with (ACCEPT + NEGOTIATE)/(CONTINUE TACTICAL + NEGOTIATE) options. The pilot normally chooses (ACCEPT + NEGOTIATE) (vi), resulting in the FMS sending a COTRAC initiation request to ATC, activating the new trajectory, switching its VNAV, LNAV, and AT control back to 4D mode, and displaying 4D and NEGOTIATING mode flags, together with the NOT CLEARED flag if the current part of the trajectory is not cleared. This returns the system to the initial condition, but with a revised trajectory that may or may not be superseded by the following negotiation process.

Note (i) If the crew does not wish to hold current speed or maintain current vertical profile, they can negotiate with ATC and select tactical control of these parameters or create a new trajectory. Additional tactical control can be implemented at any time during the sequence.
Note (ii) This trajectory is based on the current position of the aircraft and the heading projected for 30 (TBC) minutes. It is NOT used to control the aircraft, only to perform a Minimum Off Route Altitude (MORA) check to ensure that any potential conflict due to a current vertical manoeuvre is detected and indicated to the crew. How the crew reacts to any indicated conflict depends on the phase of the flight and the expected operations in that region - if the crew believes that the current vertical rate is not appropriate, they may contact ATC for confirmation of the vertical profile.
Note (iii) VSUS is VNAV suspended and SSUS is SPD suspended, to differentiate this from HLD cases. If no vertical manoeuvre were in progress at the time of message, these flags would have been set immediately on ACCEPT.
Note (iv) Another scenario for returning to 4D strategic control is that the ATC could initiate a re-negotiation of the 4D trajectory, ending with delivery of a cleared trajectory, instead requesting RESUME OWN NAVIGATION.
Note (v) It is assumed that the ATC command to resume own navigation clears the aircraft to return to its original trajectory by the most direct route. Any re-negotiation will normally be only to re-establish RTAs on the route.
Note (vi) Since the return to route is a command from ATC, it is unlikely that the pilot will select the (CONTINUE TACTICAL + NEGOTIATE) option, which would leave the aircraft on the same heading while the re-negotiation took place.

3.3.1.10.2.1.3 Altitude

1. Initial state: FMS - Full Strategic Mode (4D Trajectory Active; Automatic Guidance)
   Displays show 4D mode flags
   MCP - FMS Mode (LNAV engaged; VNAV engaged; AT engaged).
2. ATC requests altitude Z ft.
3. "MSG" annunciation and advisory alert inform crew that a tactical request has been received.
4. Pilot checks message, normally has no problem, and presses ACCEPT key (other option is REJECT).

5. FMS sends WILCO to ATC, switches its VNAV control to VTAC mode (internal FMS tactical mode, MCP settings do not change), and sets LNAV+VTAC+RTA mode flags on displays.
6. FMS continues with 2D+Time strategic control (2D Trajectory Active; LNAV plus RTA). Fuel status and ETA effects are continuously updated for monitoring and display.
7. FMS monitors previously cleared 4D trajectory and alerts crew if constraints can no longer be met. Progress along the active 2D trajectory continues to be displayed, with an indication of altitude deviation. The alert is given when the aircraft is within TBD minutes of the constraint that cannot be met. The alert ensures that the crew are aware that a trajectory re-negotiation process is required before full 4D strategic guidance can be selected again.
8. When ATC wishes to end the tactical altitude command, they request RESUME OWN NAVIGATION (or similar). (i)
9. "MSG" annunciation and advisory alert inform crew that the end of tactical command has been received.
10. If the FMS can still meet all constraints and RTAs without significant cost, it presents the pilot with the message, a regenerated trajectory (using existing constraints plus any received with the end tactical control message from ATC), and ACCEPT/ REJECT options. The pilot normally chooses ACCEPT, resulting in the FMS sending WILCO to ATC, activating the new trajectory, switching its VNAV control back to 4D mode, and displaying 4D mode flags. This returns the system to the initial condition, but with a revised trajectory.
11. If the FMS can no longer meet all RTAs (ii), or if there is significant cost in meeting the existing constraints, it presents the pilot with the message, regenerates a trajectory based on optimum cost RTAs plus any constraints received with the end tactical control message from ATC, flags the relevant part(s) of the new trajectory as NOT CLEARED, and presents the pilot with (ACCEPT + NEGOTIATE)/(CONTINUE TACTICAL + NEGOTIATE) options. The pilot normally chooses (ACCEPT + NEGOTIATE) (iii), resulting in the FMS sending a COTRAC initiation request to ATC, activating the new trajectory, switching its VNAV control back to 4D mode, and displaying 4D and NEGOTIATING mode flags, together with the NOT CLEARED flag if the current part of the trajectory is not cleared. This returns the system to the initial condition, but with a revised trajectory that may or may not be superseded by the following negotiation process.

Note (i) Another scenario for returning to 4D strategic control is that the ATC could initiate a re-negotiation of the 4D trajectory, ending with delivery of a cleared trajectory, instead requesting RESUME OWN NAVIGATION.
Note (ii) Even though the 4D clearance may have been lost, the aircraft continues to fly on the cleared 2D trajectory – it is only the RTAs and any intermediate altitude points before the original trajectory is regained that need to be re-negotiated.
Note (iii) Selecting the (CONTINUE TACTICAL + NEGOTIATE) option would have resulted in the FMS continuing on the 2D route whilst maintaining tactical altitude Z ft while the re-negotiation takes place.

3.3.1.10.2.1.4 Route

Route commands request a track parallel to the current one (offset) or add extra points to the current trajectory (direct to). Adding extra points is treated by the FMS like generation of a new trajectory, so it is not described further in this section. Parallel operation is treated as a tactical command by the FMS, so its mode of operation is described.
It should be noted that in the long term, offsets will be replaced by the ATC adding constraints to the trajectory (for instance to avoid a hazard) but in the short term, offsets will continue to be used and so the FMS must be capable of handling them.
One reason for wishing to move towards the use of constraints rather than offsets is that an offset command in combination with a vertical manoeuvre can result in vertical rates that are different from

those defined in the original trajectory if they are performed on curved tracks. The operation with vertical rates will attempt to preserve the negotiated rate, resulting in early top of climb or bottom of descent on an outside curve offset and late top of descent or bottom of climb on an inside curve offset. Applying constraints and re-generating and re-negotiating the trajectory provides a more predictable solution.
Also, RTAs can be lost due to the time required to get to the offset and return, whereas applying constraints and re-generating and re-negotiating the trajectory results in new, defined RTAs.
Because the aircraft track is dependent on the active trajectory, the whole 4D active trajectory is maintained.

1. Initial state: FMS - Full Strategic Mode (4D Trajectory Active; Automatic Guidance)
   Displays show 4D mode flags
   MCP - FMS Mode (LNAV engaged; VNAV engaged; AT engaged).
2. ATC requests offset W nm.
3. "MSG" annunciation and advisory alert inform crew that a tactical request has been received.
4. The FMS generates a new trajectory based on the existing trajectory and the offset command (including start or end points if specified), and checks these against the stored MORA database for conflict.
5. The crew is presented with the message and the revised trajectory, which the pilot checks, normally has no problem, and presses ACCEPT key (other option is REJECT).
6. FMS sends WILCO to ATC, switches to the new trajectory (whilst still in full 4D FMS strategic mode, MCP settings do not change), and sets 4D+OFFS mode flags on displays.
7. FMS continues with 4D strategic control. Fuel status and ETA effects are continuously updated for monitoring and display.
8. FMS monitors previously cleared 4D trajectory and alerts crew if constraints can no longer be met. Progress along the original active trajectory continues to be displayed, with an indication of distance deviation. The alert is given when the aircraft is within TBD minutes of the constraint that cannot be met. The alert ensures that the crew are aware that a trajectory re-negotiation process is required when return is made to the original trajectory.
9. When ATC wishes to end the tactical OFFSET, they request RESUME OWN NAVIGATION (or similar). (i)
10. "MSG" annunciation and advisory alert inform crew that the end of tactical command has been received.
11. If the FMS can still meet all constraints and RTAs in the original trajectory without significant cost, it presents the pilot with the message, a regenerated trajectory (using existing constraints plus any received with the end tactical control message from ATC), and ACCEPT/ REJECT options. The pilot normally chooses ACCEPT, resulting in the FMS sending WILCO to ATC and activating the new trajectory. This returns the system to the initial condition, but with a revised trajectory.
12. If the FMS can no longer meet all RTAs or altitudes (ii) in the original trajectory, or if there is significant cost in meeting the existing constraints, it presents the pilot with the message, regenerates a trajectory based on optimum cost RTAs plus any constraints received with the end tactical control message from ATC, flags the relevant part(s) of the new trajectory as NOT CLEARED, and presents the pilot with (ACCEPT + NEGOTIATE)/(CONTINUE TACTICAL + NEGOTIATE) options. The pilot normally chooses (ACCEPT + NEGOTIATE) (iii), resulting in the FMS sending a COTRAC initiation request to ATC, activating the new trajectory, and displaying 4D and NEGOTIATING mode flags, together with the NOT CLEARED flag if the current part of the trajectory is not cleared. This returns the system to the initial condition, but with a revised trajectory that may or may not be superseded by the following negotiation process.

Note (i) Another scenario for returning to 4D strategic control is that the ATC could initiate a re-negotiation of the 4D trajectory, ending with delivery of a cleared trajectory, instead requesting RESUME OWN NAVIGATION.
Note (ii) Even though the 4D clearance may have been lost, the aircraft continues to fly on the cleared 2D trajectory – it is only the RTAs and any intermediate altitude points before the original trajectory is regained that need to be re-negotiated.
Note (iii) Selecting the (CONTINUE TACTICAL + NEGOTIATE) option would have resulted in the FMS continuing on the offset 3D route while the re-negotiation takes place.

3.3.1.10.2.2 Delegated Manoeuvre Requests During Strategic Operation

3.3.1.10.2.2.1 Spacing Procedures

Although 2 types of Spacing procedure are defined in the CDTI/ASAS section (In-descent Spacing and Level Flight Spacing), the aircraft systems treat them identically. There are, however, 2 different Spacing modes: distance spacing and time spacing, that are very similar for the crew.
The manoeuvres are flown as extensions to the active trajectory, so they are treated by the FMS as dynamically updated strategic operations.
Details of the manoeuvres are given in the CDTI/ASAS section.

1. Initial state: FMS - Full Strategic Mode (4D Trajectory Active; Automatic Guidance)
   Displays show 4D mode flags
   MCP - FMS Mode (LNAV engaged; VNAV engaged; AT engaged).
2. ATC instruct In-descent/Level Flight Spacing.
3. "MSG" annunciation and advisory alert inform crew that a delegated maneuver instruction has been received.
4. The FMS generates a new trajectory based on the existing trajectory and the state and intent of the target (to perform a merge behind etc.).
5. The crew is presented with the message, the highlighted target, and the revised trajectory, which the pilot checks, normally has no problem, and presses ACCEPT key (other option is REJECT).
6. FMS sends WILCO to ATC, switches to the new trajectory (whilst still in full 4D FMS strategic mode, MCP settings do not change), and sets 4D+SK mode flags on displays.
7. FMS continues with 4D strategic control as the ownship takes position behind the target at the specified distance. As the target passes through the point where the maneuver is to start, new constraints are generated at a regular interval of TBD s, each based on the state and intent of the target, and the trajectory is automatically re-generated and then automatically accepted each time a new constraint is added.
8. Fuel status and ETA effects are continuously updated for monitoring and display.
9. FMS monitors previously cleared 4D trajectory and alerts crew if original RTAs can no longer be met. Progress along the original active trajectory continues to be displayed, with an indication of distance and time deviation. The alert is given when the aircraft is within TBD minutes of the constraint that cannot be met. The alert ensures that the crew are aware that a trajectory re-negotiation process is required when return is made to the original trajectory.
10. When ATC wishes to end the Spacing, they request RESUME OWN NAVIGATION (or similar). (i)
11. "MSG" annunciation and advisory alert inform crew that the end of Spacing command has been received.
12. If the FMS can still meet all constraints and RTAs in the original trajectory without significant cost, it presents the pilot with the message, a regenerated trajectory (using existing constraints plus any received with the end Spacing message from ATC), and ACCEPT/ REJECT options.

The pilot normally chooses ACCEPT, resulting in the FMS sending WILCO to ATC, displaying 4D mode flag, and activating the new trajectory. This returns the system to the initial condition, but with a revised trajectory.

13. If the FMS can no longer meet all RTAs (ii) in the original trajectory, or if there is significant cost in meeting the existing constraints, it presents the pilot with the message, regenerates a trajectory based on optimum cost RTAs plus any constraints received with the end Spacing message from ATC, flags the relevant part(s) of the new trajectory as RTA NOT CLEARED, and presents the pilot with (NEGOTIATE) option only. The pilot enters (NEGOTIATE), resulting in the FMS sending a COTRAC initiation request to ATC, activating the new trajectory, and displaying 4D and NEGOTIATING mode flags, together with the RTA NOT CLEARED flag if the current part of the trajectory is not cleared. This returns the system to the initial condition, but with a revised trajectory that may or may not be superseded by the following negotiation process.

Note (i) Another scenario for returning to 4D strategic control is that the ATC could initiate a re-negotiation of the 4D trajectory, ending with delivery of a cleared trajectory, instead requesting RESUME OWN NAVIGATION.
Note (ii) Even though the 4D clearance may have been lost, the aircraft continues to fly on the original cleared 3D trajectory – it is only the RTAs that need to be re-negotiated. This is because all station keeping delegations do not affect the ownship's 3D (lateral plus vertical) trajectory.

3.3.1.10.2.2.2 Vertical Crossing and Passing

Delegated crossing and passing manoeuvres are bounded activities that are represented as modifications to the active trajectory. Therefore they do not represent a change to a tactical mode within the FMS and do not require an action after the manoeuvre to return to the original trajectory.

1. Initial state: FMS - Full Strategic Mode (4D Trajectory Active; Automatic Guidance)
   Displays show 4D mode flags
   MCP - FMS Mode (LNAV engaged; VNAV engaged; AT engaged).
2. ATC requests Lateral crossing/passing maneouvre.
3. "MSG" annunciation and advisory alert inform crew that a delegated manoeuvre request has been received.
4. The FMS generates a new trajectory based on the existing trajectory, the requested manoeuvre details, and the state and intent of the target, and checks these against the stored MORA database for conflict.
5. The crew is presented with the message, identification of the target, and the revised trajectory, which the pilot checks, normally has no problem, and presses ACCEPT key (other option is REJECT).
6. FMS sends WILCO to ATC, switches to the new trajectory (whilst still in full 4D FMS strategic mode, MCP settings do not change), and sets 4D+VRTP/VRTC mode flags on displays.
7. Fuel status and ETA effects are continuously updated for monitoring and display.
8. FMS monitors new 4D trajectory and alerts crew if original RTAs or altitudes can no longer be met. Progress along the new active trajectory continues to be displayed. The alert is given when the aircraft is within TBD minutes of the constraint that cannot be met. The alert ensures that the crew are aware that a trajectory re-negotiation process is required.
9. When the FMS detects that the ownship has rejoined the original trajectory it alerts the crew that the manoeuvre is complete, sets 4D mode flags on displays, and automatically notifies ATC.
10. If the FMS can still meet all constraints and RTAs in the original trajectory without significant cost, no further action is required by the crew or ATC.

11. If the FMS can no longer meet all RTAs (i) in the original trajectory, or if there is significant cost in meeting the existing constraints, it presents the pilot with the message, regenerates a trajectory based on optimum cost RTAs plus any constraints received with the end tactical control message from ATC, flags the relevant part(s) of the new trajectory as RTA NOT CLEARED, and presents the pilot with ACCEPT and EDIT options. The pilot normally enters ACCEPT, resulting in the FMS sending a COTRAC initiation request to ATC and displaying the NEGOTIATING mode flag, together with the RTA NOT CLEARED flag if the current part of the trajectory is not cleared. This returns the system to the initial condition, but with a revised trajectory that may or may not be superseded by the following negotiation process.

Note (i) Even though the 4D clearance may have been lost, the aircraft continues to fly on the cleared 3D trajectory – it is only the RTAs and any intermediate altitude points before the original trajectory is regained that need to be re-negotiated. The need for re-negotiation can usually be predicted as soon as the request for manoeuvre is received from ATC, and should be completed before the ownship returns to its original 3D trajectory.

3.3.1.10.2.2.3 Lateral Crossing and Passing

Delegated crossing and passing manoeuvres are bounded activities that are represented as modifications to the active trajectory. Therefore they do not represent a change to a tactical mode within the FMS and do not require an action after the manoeuvre to return to the original trajectory.

1. Initial state: FMS - Full Strategic Mode (4D Trajectory Active; Automatic Guidance)
   Displays show 4D mode flags
   MCP - FMS Mode (LNAV engaged; VNAV engaged; AT engaged).
2. ATC requests Lateral crossing/passing manoeuvre.
3. “MSG” annunciation and advisory alert inform crew that a delegated manoeuvre request has been received.
4. The FMS generates a new trajectory based on the existing trajectory, the requested manoeuvre details, and the state and intent of the target, and checks these against the stored MORA database for conflict.
5. The crew is presented with the message, identification of the target, and the revised trajectory, which the pilot checks, normally has no problem, and presses ACCEPT key (other option is REJECT).
6. FMS sends WILCO to ATC, switches to the new trajectory (whilst still in full 4D FMS strategic mode, MCP settings do not change), and sets 4D+LATP/LATC mode flags on displays.
7. Fuel status and ETA effects are continuously updated for monitoring and display.
8. FMS monitors new 4D trajectory and alerts crew if original RTAs or constraints can no longer be met. Progress along the new active trajectory continues to be displayed. The alert is given when the aircraft is within TBD minutes of the constraint that cannot be met. The alert ensures that the crew are aware that a trajectory re-negotiation process is required.
9. When the FMS detects that the ownship has rejoined the original trajectory it alerts the crew that the manoeuvre is complete, sets 4D mode flags on displays, and automatically notifies ATC.
10. If the FMS can still meet all constraints and RTAs in the original trajectory without significant cost, no further action is required by the crew or ATC.
11. If the FMS can no longer meet all RTAs (i) in the original trajectory, or if there is significant cost in meeting the existing constraints, it presents the pilot with the message, regenerates a trajectory based on optimum cost RTAs plus any constraints received with the end tactical control message from ATC, flags the relevant part(s) of the new trajectory as RTA NOT CLEARED, and presents the pilot with ACCEPT and EDIT options. The pilot normally enters ACCEPT, resulting in the

FMS sending a COTRAC initiation request to ATC and displaying the NEGOTIATING mode flag, together with the RTA NOT CLEARED flag if the current part of the trajectory is not cleared. This returns the system to the initial condition, but with a revised trajectory that may or may not be superseded by the following negotiation process.

Note (i) Even though the 4D clearance may have been lost, the aircraft continues to fly on the cleared 3D trajectory – it is only the RTAs plus any intermediate altitude points before the original trajectory is regained that need to be re-negotiated. The need for re-negotiation can usually be predicted as soon as the request for manoeuvre is received from ATC, and should be completed before the ownship returns to its original 3D trajectory.

3.3.1.10.2.3 Transitions In Airspace Type

It is assumed to be a prerequisite for operation in Free Flight Airspace that an aircraft is equipped with CDTI/ASAS and is able to perform conflict avoidance manoeuvres.

However, conflict avoidance manoeuvring can be performed automatically (the preferred option) or manually (not preferred as it will increase pilot workload, but might be done accidentally by the crew or under some system failure conditions), so the capability must be present in the system to handle transitions with mixed strategic and tactical clearances (nD and [4-n]D).

As noted previously, the airspace type is always displayed for reasons of pilot awareness, as the procedures in different airspace types vary.

Entry to, and exit from, FFAS is normally performed at a 4D constraint so that ATC have full control over transitions. If the transition is performed tactically, ATC will have full responsibility for guiding to, and timing of, the transition point.

Responsibility for separation for entry into the FFAS from MAS is expected to be the aircraft’s. Once an agreed entry point has been negotiated with ATC, the aircraft will maintain this, unless the aircraft detects a conflict within the FFAS. If this is the case, then the crew will re-negotiate the entry point with the ATC, stating the reason for the change.

Note that within FFAS, the aircraft has full responsibility for its movement, and the preferred procedure for ensuring correct operation is to use automatic 4D guidance (reducing crew workload and guaranteeing RTA of the FFAS exit).

This means that on entry to FFAS, a transition to automatic 4D guidance is the preferred action, requiring a trajectory to be re-generated if any tactical commands were active at the time of transition.

At any time, within any airspace, the crew is at liberty to change to manual control, either by disengaging the autopilot or FMS entirely or by disengaging individual autopilot or FMS modes (lateral, vertical, or speed). Using manual control, the crew may still use the FMS for guidance cues and are required to use the CDTI within FFAS.

Approach to the exit from FFAS is expected to occur with 4D strategic guidance active (usually automatic control) but ATC are able to request a changed state at the transition, which could involve tactical control.

The following section describes transition from MAS to FFAS with any one degree of freedom (lateral, vertical, speed) in tactical mode and with all degrees of freedom in tactical mode (in fact the system will all handle combinations of tactical and strategic – the various descriptions can be read together to illustrate the effects) and then describes the same degrees of freedom becoming tactical on exit from FFAS back into MAS.

Note that other types of airspace are not described: all special airspace is assumed to be MAS apart from UMAS which is treated by the FMS in the same way as FFAS (TBC).

3.3.1.10.2.3.1 MAS to FFAS with Tactical Speed Control

Strategic 3D control (LNAV plus VNAV) to a negotiated trajectory will deliver the aircraft to the defined point in space for transition, but ATC is responsible for timing of the transition.

1. Initial state: FMS - Partial Strategic Mode (3D (LNAV plus VNAV) Trajectory Active with speed under tactical input (STAC); Automatic Guidance)
   Displays show LNAV+VNAV+STAC mode flags
   MCP - FMS Mode (LNAV engaged; VNAV engaged; AT engaged).

2. FMS generates "TBD" annunciation and advisory alert to inform the crew that a transition will occur to FFAS in TBD minutes, based on the active 3D (LNAV plus VNAV) trajectory plus the projected time. (i)
3. ATC notes transition about to occur to FFAS and sends clearance for entry. (ii)
4. "MSG" annunciation and advisory alert inform crew that a FFAS entry clearance has been received.
5. The FMS generates a new trajectory based on the existing trajectory, the projected entry time to FFAS, and the results of an ASAS conflict probe into FFAS.
6. The crew is presented with the message and the revised trajectory, which the pilot checks, normally has no problem, and presses ACCEPT key (other option is REJECT). (iii) (iv) (v)
7. FMS sends WILCO to ATC, switches to the new trajectory (whilst still in 3D (LNAV plus VNAV) FMS strategic mode plus tactical speed mode, MCP settings do not change).
8. When the FMS detects arrival at the FFAS transition point, it generates a "TBD" annunciation and advisory alert to inform the crew that FFAS has been entered, sends a message to ATC to indicate that the FFAS transition has been made, activates full 4D strategic guidance (FMS speed mode changes from STAC to RTA), and displays show 4D, ASAS, and FFAS flags.
9. Operation within FFAS is now as described in the Autonomous Operation section.

Note (i) The sequence of ATC sending the clearance and the crew being warned of the transition from the active trajectory may vary.
Note (ii) This clearance may have been given much earlier (for instance as part of a strategic clearance on entry to this sector). If clearance has not been received from ATC to enter FFAS within TBD minutes of entry, the crew is expected to contact ATC to query this.
Note (iii) If the conflict probe had required a deviation from the active 3D trajectory, the crew will be alerted and are required to contact ATC (using REJECT which causes an UNABLE message, then voice contact) for a route deviation clearance before accepting the new trajectory. This is not a normal event, however, as use of a FFAS buffer zone prevents conflicting traffic movements during transition.
Note (iv) The revised trajectory could be downloaded and passed to the FFAS exit sector to provide advance information on any exit RTA changes for planning purposes. This would be a ground initiated activity.
Note (v) If changes occur to the tactical command before entry to FFAS, the trajectory will be re-generated again.

3.3.1.10.2.3.2 MAS to FFAS with Tactical Altitude Control

Strategic 3D control (LNAV plus RTA) to a negotiated trajectory will deliver the aircraft to the defined lat/lon for transition at the required time, but ATC is responsible for altitude of the transition.
This means that entry to FFAS might not occur at the point expected in the 4D trajectory, as the lateral shape of the boundary may change with altitude (the most extreme case is that FFAS does not exist at the altitude that the aircraft is flying).

1. Initial state: FMS - Partial Strategic Mode (3D (LNAV plus RTA) Trajectory Active with altitude under tactical input (VTAC); Automatic Guidance)
   Displays show LNAV+VTAC+RTA mode flags
   MCP - FMS Mode (LNAV engaged; VNAV engaged; AT engaged).
2. FMS generates "TBD" annunciation and advisory alert to inform the crew that a transition will occur to FFAS in TBD minutes, based on the active 3D (LNAV plus RTA) trajectory plus the projected altitude. (i)
3. ATC notes transition about to occur to FFAS and sends clearance for entry. (ii)
4. "MSG" annunciation and advisory alert inform crew that a FFAS entry clearance has been received.

5. The FMS generates a new trajectory based on the existing trajectory, the projected entry altitude to FFAS, and the results of an ASAS conflict probe into FFAS.
6. The crew is presented with the message and the revised trajectory, which the pilot checks, normally has no problem, and presses ACCEPT key (other option is REJECT). (iii) (iv) (v)
7. FMS sends WILCO to ATC, switches to the new trajectory (whilst still in 3D (LNAV plus RTA) FMS strategic mode plus tactical vertical mode, MCP settings do not change).
8. When the FMS detects arrival at the FFAS transition point, it generates a "TBD" annunciation and advisory alert to inform the crew that FFAS has been entered, sends a message to ATC to indicate that the FFAS transition has been made, activates full 4D strategic guidance (FMS vertical mode changes from VTAC to VNAV), and displays show 4D, ASAS, and FFAS flags.
9. Operation within FFAS is now as described in the Autonomous Operation section.

Note (i) The sequence of ATC sending the clearance and the crew being warned of the transition from the active trajectory may vary.
Note (ii) This clearance may have been given much earlier (for instance as part of a strategic clearance on entry to this sector). If clearance has not been received from ATC to enter FFAS within TBD minutes of entry, the crew is expected to contact ATC to query this.
Note (iii) If the conflict probe had required a deviation from the active 3D trajectory, the crew will be alerted and are required to contact ATC (using REJECT which causes an UNABLE message, then voice contact) for a route deviation clearance before accepting the new trajectory. This is not a normal event, however, as use of a FFAS buffer zone prevents conflicting traffic movements during transition.
Note (iv) The revised trajectory could be downloaded and passed to the FFAS exit sector to provide advance information on any exit RTA changes for planning purposes. This would be a ground initiated activity.
Note (v) If changes occur to the tactical command before entry to FFAS, the trajectory will be re-generated again.

3.3.1.10.2.3.3 MAS to FFAS with Tactical Lateral Control

Strategic 2D control (VNAV plus RTA) to a negotiated trajectory will normally deliver the aircraft to the defined altitude for transition at the required time, but ATC is responsible for lateral position of the transition. This will not be true if the original trajectory required altitude changes or speed changes that have been suspended due to the tactical control of track.
This means that entry to FFAS might not occur at the point expected in the 4D trajectory, as the vertical shape of the boundary may change with lateral position (the most extreme case is that FFAS does not exist on the track that the aircraft is flying).

1. Initial state: FMS - Partial Strategic Mode (2D (VNAV plus RTA) Trajectory Active with lateral under tactical input (LTAC); Automatic Guidance)
   Displays show LTAC+VNAV+RTA OR LTAC+VSUS+SSUS mode flags
   MCP - FMS Mode (LNAV engaged; VNAV engaged; AT engaged).
2. FMS generates "TBD" annunciation and advisory alert to inform the crew that a transition will occur to FFAS in TBD minutes, based on the active 3D (VNAV plus RTA) trajectory (or held altitude and speed, if suspended) plus the projected track. (i)
3. ATC notes transition about to occur to FFAS and sends clearance for entry. (ii)
4. "MSG" annunciation and advisory alert inform crew that a FFAS entry clearance has been received.
5. The FMS generates a new trajectory based on the existing trajectory, the projected entry lateral position to FFAS, and the results of an ASAS conflict probe into FFAS.
6. The crew is presented with the message and the revised trajectory, which the pilot checks, normally has no problem, and presses ACCEPT key (other option is REJECT). (iii) (iv) (v)

7. FMS sends WILCO to ATC, switches to the new trajectory (whilst still in 3D (VNAV plus RTA) FMS strategic mode plus tactical lateral mode, MCP settings do not change).
8. When the FMS detects arrival at the FFAS transition point, it generates a "TBD" annunciation and advisory alert to inform the crew that FFAS has been entered, sends a message to ATC to indicate that the FFAS transition has been made, activates full 4D strategic guidance (FMS lateral mode changes from LTAC to LNAV), and displays show 4D, ASAS, and FFAS flags.
9. Operation within FFAS is now as described in the Autonomous Operation section.

Note (i) The sequence of ATC sending the clearance and the crew being warned of the transition from the active trajectory may vary.
Note (ii) This clearance may have been given much earlier (for instance as part of a strategic clearance on entry to this sector). If clearance has not been received from ATC to enter FFAS within TBD minutes of entry, the crew is expected to contact ATC to query this.
Note (iii) If the conflict probe had required a deviation from the active 2D trajectory, the crew will be alerted and are required to contact ATC (using REJECT which causes an UNABLE message, then voice contact) for a route deviation clearance before accepting the new trajectory. This is not a normal event, however, as use of a FFAS buffer zone prevents conflicting traffic movements during transition.
Note (iv) The revised trajectory could be downloaded and passed to the FFAS exit sector to provide advance information on any exit RTA changes for planning purposes. This would be a ground initiated activity.
Note (v) If changes occur to the tactical command before entry to FFAS, the trajectory will be re-generated again.

3.3.1.10.2.3.4 MAS to FFAS with Full Tactical Control

ATC is totally responsible for entry to FFAS
This means that entry to FFAS is unlikely to occur at the point expected in the original 4D trajectory.

1. Initial state: FMS – Full Tactical Mode (LTAC plus VTAC plus STAC so Trajectory Not active; Automatic Guidance)
   Displays show LTAC+VTAC+STAC mode flags
   MCP - FMS Mode (LNAV engaged; VNAV engaged; AT engaged).
2. FMS generates "TBD" annunciation and advisory alert to inform the crew that a transition will occur to FFAS in TBD minutes, based on the projected track, vertical rate, and speed. (i)
3. ATC notes transition about to occur to FFAS and sends clearance for entry. (ii)
4. "MSG" annunciation and advisory alert inform crew that a FFAS entry clearance has been received.
5. The FMS generates a new trajectory based on the projected entry position to FFAS, and the results of an ASAS conflict probe into FFAS.
6. The crew is presented with the message and the revised trajectory, which the pilot checks, normally has no problem, and presses ACCEPT key (other option is REJECT). (iii) (iv) (v)
7. FMS sends WILCO to ATC, switches to the new trajectory (whilst still in Full Tactical (LTAC plus VTAC plus STAC) FMS mode, MCP settings do not change).
8. When the FMS detects arrival at the FFAS transition point, it generates a "TBD" annunciation and advisory alert to inform the crew that FFAS has been entered, sends a message to ATC to indicate that the FFAS transition has been made, activates full 4D strategic guidance (FMS mode changes from LTAC+VTAC+STAC to LNAV+VNAV+RTA), and displays show 4D, ASAS, and FFAS flags.
9. Operation within FFAS is now as described in the Autonomous Operation section.

Note (i) The sequence of ATC sending the clearance and the crew being warned of the transition from the active trajectory may vary.
Note (ii) This clearance may have been given much earlier (for instance as part of a strategic clearance on entry to this sector). If clearance has not been received from ATC to enter FFAS within TBD minutes of entry, the crew is expected to contact ATC to query this.
Note (iii) If the conflict probe had required a deviation from the active 2D trajectory, the crew will be alerted and are required to contact ATC (using REJECT which causes an UNABLE message, then voice contact) for a route deviation clearance before accepting the new trajectory. This is not a normal event, however, as use of a FFAS buffer zone prevents conflicting traffic movements during transition.
Note (iv) The revised trajectory could be downloaded and passed to the FFAS exit sector to provide advance information on any exit RTA changes for planning purposes. This would be a ground initiated activity.
Note (v) If changes occur to a tactical command before entry to FFAS, the trajectory will be re-generated again.

3.3.1.10.2.3.5 FFAS to MAS with Tactical Speed Control

When ATC is contacted for FFAS exit clearance, the response is a 3D (lateral plus vertical) strategic clearance plus a speed constraint at the FFAS exit point. In order to be at the required speed at that point, the 4D trajectory used within FFAS will be re-generated with a speed constraint at the exit point.

1. Initial state: FMS - Full Strategic Mode (4D (LNAV, VNAV. RTA) Trajectory Active; Automatic Guidance)
   Displays show 4D (LNAV+VNAV+RTA), ASAS, FFAS mode flags
   MCP - FMS Mode (LNAV engaged; VNAV engaged; AT engaged).
2. FMS generates “TBD” annunciation and advisory alert to inform the crew that a transition will occur to MAS in TBD minutes, based on the active 4D trajectory, contacts ATSU to log onto ground services, and initiates a COTRAC clearance sequence. (i)
3. ATC notes transition about to occur to MAS and sends clearance for exit from FFAS with a tactical speed request.
4. “MSG” annunciation and advisory alert inform crew that a FFAS exit clearance has been received.
5. The FMS generates a new trajectory based on the existing trajectory and the specified speed constraint at the exit point.
6. The crew is presented with the message and the revised trajectory, which the pilot checks, normally has no problem, and presses ACCEPT key (other option is REJECT).
7. FMS sends WILCO to ATC, switches to the new trajectory (whilst still in 4D FMS strategic mode, MCP settings do not change). (ii)
8. When the FMS detects arrival at the FFAS transition point, it generates a “TBD” annunciation and advisory alert to inform the crew that MAS has been entered, sends a message to ATC to indicate that the MAS transition has been made, activates 3D strategic guidance plus tactical speed (FMS speed mode changes from RTA to STAC), and displays show LNAV, VNAV, STAC, and MAS flags.
9. Operation within MAS is now as described in the Tactical Requests During Strategic Operation section.

Note (i) The sequence of ATC sending the clearance and the crew being warned of the transition from the active trajectory may vary. This is possible if the aircraft logs onto the ground system before the entry alert, in which case COTRAC could be initiated by the ground before the crew is alerted to MAS entry.
Note (ii) If changes occur to the trajectory before entry to MAS (for instance if ASAS performs Conflict Resolution for a target within FFAS), the trajectory will be re-generated again and then be re-negotiated if not all constraints can be achieved with acceptable cost.

3.3.1.10.2.3.6 FFAS to MAS with Tactical Altitude Control

When ATC is contacted for FFAS exit clearance, the response is a 3D (lateral plus RTA) strategic clearance plus vertical rate constraint at the FFAS exit point. In order to be at the required vertical rate at that point, the 4D trajectory used within FFAS will be re-generated with a vertical rate constraint at the exit point.
Note that this does not move the exit point – it only changes the vertical rate as the aircraft emerges from FFAS into MAS. If ATC wish to move the exit point, then they will change the exit position (lateral and vertical) constraint.

1. Initial state: FMS - Full Strategic Mode (4D (LNAV, VNAV, RTA) Trajectory Active; Automatic Guidance)
   Displays show 4D (LNAV+VNAV+RTA), ASAS, FFAS mode flags
   MCP - FMS Mode (LNAV engaged; VNAV engaged; AT engaged).
2. FMS generates "TBD" annunciation and advisory alert to inform the crew that a transition will occur to MAS in TBD minutes, based on the active 4D trajectory, contacts ATSU to log onto ground services, and initiates a COTRAC clearance sequence. (i)
3. ATC notes transition about to occur to MAS and sends clearance for exit from FFAS with a tactical vertical rate request.
4. "MSG" annunciation and advisory alert inform crew that a FFAS exit clearance has been received.
5. The FMS generates a new trajectory based on the existing trajectory and the specified vertical rate constraint.
6. The crew is presented with the message and the revised trajectory, which the pilot checks, normally has no problem, and presses ACCEPT key (other option is REJECT).
7. FMS sends WILCO to ATC, switches to the new trajectory (whilst still in 4D FMS strategic mode, MCP settings do not change). (ii)
8. When the FMS detects arrival at the FFAS transition point, it generates a "TBD" annunciation and advisory alert to inform the crew that MAS has been entered, sends a message to ATC to indicate that the MAS transition has been made, activates 3D strategic guidance plus tactical vertical control (FMS vertical mode changes from VNAV to VTAC), and displays show LNAV, VTAC, RTA, and MAS flags.
9. Operation within MAS is now as described in the Tactical Requests During Strategic Operation section.

Note (i) The sequence of ATC sending the clearance and the crew being warned of the transition from the active trajectory may vary. This is possible if the aircraft logs onto the ground system before the entry alert, in which case COTRAC could be initiated by the ground before the crew is alerted to MAS entry.
Note (ii) If changes occur to the trajectory before entry to MAS (for instance if ASAS performs Conflict Resolution for a target within FFAS), the trajectory will be re-generated again and then be re-negotiated if not all constraints can be achieved with acceptable cost.

3.3.1.10.2.3.7 FFAS to MAS with Tactical Lateral Control

When ATC is contacted for FFAS exit clearance, the response is a 3D (vertical plus RTA) strategic clearance plus a lateral constraint at the FFAS exit point. In order to be at the required and heading at that point, the 4D trajectory used within FFAS will be re-generated with a heading constraint at the exit point.
Note that this does not move the exit point – it only changes the heading as the aircraft emerges from FFAS into MAS. If ATC wish to move the exit point, then they will change the exit position (lateral and vertical) constraint.

1. Initial state: FMS - Full Strategic Mode (4D (LNAV, VNAV, RTA) Trajectory Active; Automatic Guidance)

Displays show 4D (LNAV+VNAV+RTA), ASAS, FFAS mode flags
MCP - FMS Mode (LNAV engaged; VNAV engaged; AT engaged).

2. FMS generates "TBD" annunciation and advisory alert to inform the crew that a transition will occur to MAS in TBD minutes, based on the active 4D trajectory, contacts ATSU to log onto ground services, and initiates a COTRAC clearance sequence. (i)
3. ATC notes transition about to occur to MAS and sends clearance for exit from FFAS with a tactical lateral request.
4. "MSG" annunciation and advisory alert inform crew that a FFAS exit clearance has been received.
5. The FMS generates a new trajectory based on the existing trajectory and the specified lateral constraint.
6. The crew is presented with the message and the revised trajectory, which the pilot checks, normally has no problem, and presses ACCEPT key (other option is REJECT).
7. FMS sends WILCO to ATC, switches to the new trajectory (whilst still in 4D FMS strategic mode, MCP settings do not change). (ii)
8. When the FMS detects arrival at the FFAS transition point, it generates a "TBD" annunciation and advisory alert to inform the crew that MAS has been entered, sends a message to ATC to indicate that the MAS transition has been made, activates 3D strategic guidance plus tactical lateral control (FMS vertical mode changes from LNAV to LTAC), and displays show LTAC, VNAV, RTA, and MAS flags.
9. Operation within MAS is now as described in the Tactical Requests During Strategic Operation section, including subsequent change of FMS mode to LTAC+VSUS+SSUS when any exiting vertical manoeuvre has been completed.

Note (i) The sequence of ATC sending the clearance and the crew being warned of the transition from the active trajectory may vary. This is possible if the aircraft logs onto the ground system before the entry alert, in which case COTRAC could be initiated by the ground before the crew is alerted to MAS entry.
Note (ii) If changes occur to the trajectory before entry to MAS (for instance if ASAS performs Conflict Resolution for a target within FFAS), the trajectory will be re-generated again and then be re-negotiated if not all constraints can be achieved with acceptable cost.

3.3.1.10.2.3.8 FFAS to MAS with Full Tactical Control

When ATC is contacted for FFAS exit clearance, the response clearance to the exit position plus heading, vertical rate, and speed constraints at the FFAS exit point. In order to be at the required velocity at that point, the 4D trajectory used within FFAS will be re-generated with heading, vertical rate, and speed constraints at the exit point.
Note that this does not move the exit point – it only changes the velocity as the aircraft emerges from FFAS into MAS. If ATC wish to move the exit point, then they will change the exit position (lateral and vertical) constraint.

1. Initial state: FMS - Full Strategic Mode (4D (LNAV, VNAV, RTA) Trajectory Active; Automatic Guidance)
   Displays show 4D (LNAV+VNAV+RTA), ASAS, FFAS mode flags
   MCP - FMS Mode (LNAV engaged; VNAV engaged; AT engaged).
2. FMS generates "TBD" annunciation and advisory alert to inform the crew that a transition will occur to MAS in TBD minutes, based on the active 4D trajectory, contacts ATSU to log onto ground services, and initiates a COTRAC clearance sequence. (i)
3. ATC notes transition about to occur to MAS and sends clearance for exit from FFAS with tactical heading, vertical rate, and speed requests.
4. "MSG" annunciation and advisory alert inform crew that a FFAS exit clearance has been received.

5. The FMS generates a new trajectory based on the existing trajectory and the specified heading, vertical rate, and speed constraints.
6. The crew is presented with the message and the revised trajectory, which the pilot checks, normally has no problem, and presses ACCEPT key (other option is REJECT).
7. FMS sends WILCO to ATC, switches to the new trajectory (whilst still in 4D FMS strategic mode, MCP settings do not change). (ii)
8. When the FMS detects arrival at the FFAS transition point, it generates a "TBD" annunciation and advisory alert to inform the crew that MAS has been entered, sends a message to ATC to indicate that the MAS transition has been made, activates full tactical control (FMS mode changes from LNAV+VNAV+RTA to LTAC+VTAC+STAC), and displays show LTAC, VTAC, STAC, and MAS flags.
9. Operation within MAS is now as described in the Tactical Requests During Strategic Operation section.

Note (i) The sequence of ATC sending the clearance and the crew being warned of the transition from the active trajectory may vary. This is possible if the aircraft logs onto the ground system before the entry alert, in which case COTRAC could be initiated by the ground before the crew is alerted to MAS entry.
Note (ii) If changes occur to the trajectory before entry to MAS (for instance if ASAS performs Conflict Resolution for a target within FFAS), the trajectory will be re-generated again and then be re-negotiated if not all constraints can be achieved with acceptable cost.

3.3.2 Trajectory Negotiation

3.3.2.1. Operation Service Description

Trajectory Negotiation is the application that, by negotiation between the aircraft and the ATC, will lead to an agreed trajectory that the aircraft will be cleared to fly to a predefined point (ie a strategic clearance).
The level of Trajectory Negotiation that can be attained between the aircraft and the ATC will mainly depend on the capability of the ATC, both in terms of the type of data link communication supported and in terms of the tools that the ATC has to support the negotiation process (such as performance models for the aircraft).
There are several levels expected with Trajectory Negotiation, and these are classed as the following :-

- Verbal Negotiation
- Basic Negotiation
- Partial Negotiation
- Full Negotiation

Verbal Negotiation is where negotiation is carried out entirely verbally. The exchange will be based on the common knowledge of the flight plan. This will be negotiated, with the ATC adding or changing information including clearance limit with optional RTA as required. The crew will review the effects any changes have on the proposed flight plan and normally will accept these changes. Any changes that cannot be accepted will be identified (by voice) to the ATC with a reason why they cannot be met. The ATC, having reviewed this new trajectory, will then give a strategic clearance to a selected point on the trajectory, with an optional associated time window (if this is not already defined by an RTA at a TCP) within which the aircraft must arrive at this point. To get to this point, it is assumed that the aircraft will fly along the agreed flight plan.

Basic Negotiation is where a basic level of data link service exists that can be used for trajectory negotiation. It is currently envisaged that a CPDLC application (such as the Airborne Clearances) and ADS application (such as FLIPCY) could be used, augmented with free text messages (over CPDLC) where necessary. As with Verbal Negotiation, the negotiation will be based around the filed flight plan. The ATC will be able to get information on the Trajectory Change Points (TCPs) from the crew via data link. These will then be checked by the ATC for consistency with the flight plan. Any inconsistencies and any ATC required change to or additional constraints will then be data linked back to the aircraft (only at a very simple level such as a change of level or waypoint) together with the clearance (limit), with an optional associated time window (if this is not already defined by an RTA at a TCP) within which the aircraft must arrive at this point, . The crew will review the changes proposed by ATC (if there are any) and clearance given by ATC, normally accept them and fly the resulting trajectory. To get to this clearance limit point, it is assumed that the aircraft will fly through the preceding TCPs already identified. Throughout this process, whenever the data link does not give the flexibility required to communicate the ATC changes or the reason why the crew cannot accept the changes, then voice communication will be used. .

Partial Negotiation is where a dedicated data link service is available that fully supports trajectory negotiation (such as that proposed under COTRAC). However, it is classed as only partial negotiation as the ATC carrying out the trajectory negotiation does not have all the controller tools required to fully make use of the information supplied within the trajectory. Therefore, the constraints supplied by the ATC will not be as tailored for the aircraft as they could be and the tolerances around the trajectory between negotiated points used by ATC will need to be larger to allow for the mismatch in the ATC prediction of the aircraft trajectory and that provided by the aircraft. This also impacts on the accuracy with which the ATC can carry out the conflict resolution with the other aircraft. There will not be any difference, from the aircraft viewpoint, of this type of negotiation and the Full Negotiation. The differences will be apparent at the ATC and will only impact the effectiveness with which any gains in system stability, planning and capacity can be attained.

Full Negotiation is where a dedicated data link service that fully supports trajectory negotiation is available and where the ATC with which the negotiation is being carried out is fully equipped for the negotiation (ie it can make full use of the trajectory provided and has suitable short and medium conflict resolution tools). With Full Negotiation, the crew will initiate negotiation with the ATC using the trajectory generated from the flight plan as a basis for negotiation. The ATC will load this trajectory information into their planning system, carry out flight plan consistency checks, short and medium term conflict detection checks and where necessary identify any changes to the trajectory by addition or modification of constraints. If the ATC have added or changed constraints, this new information will be data linked to the aircraft together with the clearance (limit), with an optional associated time window (if this is not already defined by an RTA at a TCP) within which the aircraft must arrive at this point. The crew will review, accept the changes and clearance and will fly the resulting trajectory accordingly. As the ATC has a good model of the aircraft, there should not be any instance of the aircraft being unable to comply with these constraints, therefore, the crew should always be able to accept the constraints (if the crew cannot accept them, it is expected to be an exceptional situation and therefore, voice communication will be required to resolve the problem, after first sending an UNABLE message by datalink). Once the crew has loaded the new route and/or constraints the system will re-generate the trajectory, subsequently the crew will check the new trajectory, and normally accept it. Acceptance will result in the crew activating it, sending a WILCO and, if needed by ATC, the entire (or a part of the) trajectory to the ground. The ATC, having reviewed this new trajectory, will normally be satisfied and only in remote cases will they immediately have to start another cycle of the trajectory negotiation process to correct problems with the new trajectory. To get to this point, it is assumed that the aircraft will fly along the agreed trajectory.

3.3.2.2. Scope and Objective

Trajectory Negotiation application will be active from aircraft power-up to Landing. It will provide the ability to negotiate a trajectory with the ATC (with support from AOC where appropriate, by previous communication between AOC and ATC without crew involvement, or by communication between AOC and crew, prior to the start of negotiation between crew and ATC or during a pause in the process indicated to ATC by a datalinked BEING EXAMINED/STANDBY message if time permits) from Take-off to Landing. It is not expected to cover taxiing as this will be covered by a taxi management system.

As mentioned above, the type of trajectory negotiation carried out will depend upon the type of data link service provided, the capability of the aircraft systems to provide an accurate trajectory and the ability of the ATC to model the aircraft under its control.

The aim of Trajectory Negotiation is to provide a more stable, strategic, longer term clearance to aircraft in MAS. Thus, increasing the situational awareness of the crew, reducing their workload and minimising the need for tactical control and so reducing the workload of the ATC.

It should be noted that level of communication within the ATC (ie ground to ground communication) to successfully negotiate for more than one sector has not been covered here. However, for effective implementation of Trajectory Negotiation, this issue needs to be addressed in order to provide a single point of contact for the aircraft that has, as far as possible, the same look and feel as any other ATC contact (for the same capability) and which has the authority to give long term clearances (ie across sectors).

3.3.2.3. Expected Benefits and Anticipated Constraints

3.3.2.3.1 Expected Benefits

Trajectory Negotiation is different from the current verbal clearances to a flight plan as it is to a defined end point (ie Strategic) and has the capability to provide the ATC with a very detailed accurate plan of the trajectory of the aircraft. This detailed knowledge will allow the ATC to plan more strategically, giving them the ability to resolve conflicts with other aircraft earlier and therefore, has the potential to reduce the ATC workload (as long as the required conflict detection tools are available for the initial negotiation). Also, by the ATC giving a strategic clearance, the crew will have better situational awareness and control over their flight (less reactionary).

Trajectory Negotiation, if it occurs at the ATC strategic multi-sector planner level, can provide a long term clearance (perhaps by the use of downstream clearances), significantly reducing ATC workload in the aircraft handover between sectors and improving the efficiency of the flight (as it will be stable and deconflicted with other traffic earlier). With the greater accuracy with which the predicted position of the aircraft is known, the capacity of the airspace can be improved. This can be achieved as the need for an additional safety margin around the trajectory is reduced with the ATC and the crew now having the same picture of the aircraft's trajectory.

3.3.2.3.2 Anticipated Constraints

Minimum Trajectory Negotiation can be performed in 2D or 2D plus altitude, but for it to work effectively, the aircraft needs the ability to accurately predict its trajectory in 2D plus time and ideally in 4D. Therefore, within MA-AFAS it is expected that this application will depend upon Trajectory Navigation being available.

ATC may prefer to provide a mixed strategic and tactical clearance, where combinations of heading, altitude, or speed may be given separately from remaining strategic clearance. The FMS must be capable of operating with any modes (LNAV, VNAV, SPEED) in strategic or tactical control.

ATC must have a certain level of knowledge of the aircraft performance capability to be able to add or modify any constraints for the aircraft in a manner that means that the aircraft is highly likely to be able to comply with the changes.

Under Verbal or Basic Negotiation, the ATC do not get sight of the trajectory to which the aircraft is intending to fly. A level of knowledge of the trajectory is known by the ATC (through the flight plan and/or any TCP information downlinked automatically) but an exact correlation does not exist. There is obviously a risk of difference between the crew understanding of the aircraft trajectory and the ATC's. This will have to be covered by allowing larger tolerances within the clearance to compensate for the inaccuracies. As a result, this will mean sub optimum use of airspace (although it should be no worse than today's airspace usage).

To ensure that modifications to the trajectory can be proposed (by aircrew or ATC), reviewed, revised, and cleared before the aircraft enters the part of the trajectory being negotiated and before the optimum flight profile is affected, delays in communications and trajectory review tools on the ground and in the air must be minimised.

Data link band width will be a consideration for full trajectory negotiation. It might be that the data link is not able to support the negotiation process even though functionally both ground and air support full trajectory negotiation. In this case, the level of information required for both the ground and air to have the same understanding of the trajectory will have to be carefully reviewed.

For an efficient trajectory to maintained, within controlled airspace, the ATC need to provide follow-on clearances to the trajectory with sufficient time so that the aircraft does not have to revert to tactical control. Also, with the current sectorisation of the airspace over Europe, the length of the clearances could be very short, reducing the benefits of the strategic clearance.

3.3.2.4. Human Factors

The crew will need the ability to review the trajectory proposed by the FMS to meet the flight plan. They will also need to be able to review, add, modify and delete any constraints, whether generated by them, the AOC or the ATC. These constraints can be in 4D and therefore, they will need HMI devices that allow presentation and control of this information.

The crew will also need to verify the state of the negotiation process, ie whether they are still awaiting a response from the ATC. They will also need information on when they are getting close to the end of their clearance in order to initiate further request for clearances with sufficient time to avoid having to revert to tactical clearances. Also, as the clearances are only required under MAS, the crew will need awareness of what airspace type they are in and which type they will enter next in order to determine when the clearances need to start and stop and when they need to be negotiated.

3.3.2.5. Operating Method Without Operation Application

Without trajectory negotiation, it is expected that the ATC's method of clearing aircraft will remain mainly tactical based (ie cleared to a heading, an altitude, etc), whether verbal or over data link. Some clearances direct to a waypoint (which is strategic) will be given, but cannot be predicted by the crew. The nature of these controls will be effectively tactical, with the crew having little knowledge of when and exactly what the ATC will clear them to fly next. Note that clearances may also be given for a whole procedure (SID or STAR), and that these are strategic.

This mainly tactical regime has the effect that the crew cannot plan their flight effectively as they cannot accurately predict what they will be cleared to fly next. Also, the ATC has to have a very active role in the flight of the aircraft, in busy airspace constantly monitoring to determine when to issue the next tactical command. This reduces the control that the crew can have over their flight (through the planning and negotiation process) and keeps the workload on the ATC high. Also, the approach is very short term, where the controller is only looking to resolve conflicts normally less than 15 minutes ahead (due to the size of the sector and complexity of the traffic movement).

3.3.2.6. Operating Method With Operation Application

As mentioned above, there are expected to be 4 possible types of Trajectory Negotiation. Their anticipated operation is described below.

In all cases, it is assumed that initial trajectory negotiation (ie before the aircraft has taken-off) is initiated by the aircraft. However, subsequent trajectory negotiation can be either ground or air initiated.

It is not practicable to fly a planned trajectory exactly, so a tolerance must be permitted around it. Allowed maximum errors are specified in RNP and RTA definitions (RTCA-236A / ED-75A). Actual error limits to be applied are TBD.

It should be noted that it is assumed that the trajectory used as the basis of the negotiation is the optimum for the aircraft through the given constraints. Therefore a significant tolerance around the trajectory (which in theory gives the aircraft more flexibility in flying the trajectory) will not provide significant benefit. The main aim of the tolerance will be to avoid over controlling the aircraft to try to maintain it exactly on the trajectory when inaccuracies caused by system time lags and small differences between forecast and actual meteorological conditions occur, with larger differences, causing inability to maintain the trajectory, causing the trajectory to be regenerated.

The following sections look at each negotiation type (Verbal, Basic, Partial, and Full) and then further breaks each one down into the various stages of negotiation that are expected (pre-flight (departure clearance or "ATC clearance"), pre-flight (ready for start-up), in-flight (strategic clearance – initial or extension), in-flight (flight crew initiated modifications), and in-flight (ATC initiated modifications).

3.3.2.6.1 Verbal Negotiation

Verbal Negotiation uses voice communication between the ATC and the crew only. It assumes that no data link capability exists.

a. Pre-flight clearance delivery – expected sequence of events:

1. A flight plan for the aircraft is filed with the ATC in the normal manner and any take-off slot information has been obtained as required (by the AOC). AOC has prepared an operational flight plan for the flight crew.
2. The crew checks out the operational flight plan by using the FMS to generate a trajectory from the operational flight plan and ATIS using information such as the slot information, the forecast meteorological conditions, weight and balance information, take-off runway, SID.
3. The crew requests (verbal) clearance for the flight from ATC.
4. The ATC reviews the flight plan and determines whether there will be any conflict with other traffic within the sectors along the route (e.g. CFMU query).
5. If required, the ATC adds constraints to the flight plan (verbally only, so simple, i.e. in terms of slot changes) and provides these additional constraints to the flight crew as part of the departure clearance. The departure clearance contains at least the clearance limit (e.g. destination), take-off runway, SID and estimated time of departure (ETD).
6. Flight crew reads back the clearance and inserts/modifies applicable information in the FMS, then re-generates the trajectory.

b. Ready for start-up in pre-flight – expected sequence of events is:

1. Flight crew reports ready for start-up and, if needed, 'estimated time over waypoints' to a limited extent.
2. CFMU performs a refined full flight flow planning.
3. ATC freezes ground movement and departure planning, resulting amongst others in an accurate ETD.
4. ATC informs flight crew of refined ETD.
5. Flight crew inserts/modifies ETD in the FMS then re-generates the trajectory.

c. In-flight strategic clearance (initial/extension either after take-off or when nearing existing clearance limit) – expected sequence of events is:

1. (Optional) Flight crew request a strategic clearance extension
2. ATC issues an initial strategic clearance or an extension of the existing strategic clearance, i.e. cleared to a point on the flight plan where the path to that point is as defined by the flight plan (as modified by ATC).
3. Flight crew normally accepts strategic clearance and enters clearance limit into FMS.

d. In-flight for flight crew initiated modifications – expected sequence of events is:

1. Flight crew modifies route and/or constraints, FMS regenerates the trajectory and subsequently the flight crew reviews it.
2. Flight crew requests (verbally) route modification or another flight level together with the reason for the request (e.g. due to turbulence).
3. ATC reviews requested modifications and a) rejects it, b) clears as requested (strategic clearance) or c) modifies routes/constraints and issues strategic clearance (including modifications).
4. Flight crew normally accepts the clearance, modifies the route/constraints (if necessary), re-generates the trajectory, and activates it.

e. In-flight for ATC initiated modifications – expected sequence of events is:
1. ATC modifies route and/or constraints in order to solve conflict, to sequence aircraft and so on.
2. ATC issues strategic clearance including modified route/constraints.
3. Flight crew normally accepts the clearance, modifies the route/constraints, re-generates the trajectory, and activates it.

Note: In all cases where the crew cannot comply with ATC instructions (route modification, altitude/time constraints, strategic clearance, etc.) they will contact ATC. Rejection of ATC instructions will be very unlikely.

It should be noted that the ATC do not get sight of the trajectory to which the aircraft is flying (although all the waypoints should be as filed in the flight plan and altered by the ATC).

Also, it is expected that the ATC have a certain level of knowledge of the performance of the aircraft and therefore, will only rarely give the crew additional or modified constraints to their flight plan that they are unable to meet.

3.3.2.6.2 Basic Negotiation

Basic Negotiation is where a basic level of data link service exists that can be used for trajectory negotiation. It is assumed that information such as TCPs for the trajectory, simple ATC changes or additions to flight plan and basic clearances can be communicated over the data link.

The same sequence will be followed as for verbal negotiations, with as main difference the use of data link to exchange the same information. This means that the flight crew has to accept the automatically loaded uplinked instructions in the FMS instead of inserting them manually.

Furthermore, intent data in the form of TCP's will be transmitted to ATC (ADS-B, ADS-C)
- whenever requested by ATC (usually to support a new manual negotiation)
- along with each flight plan modification request from the flight crew.

Note: depending on the availability of ATC tools, the basis for air traffic control may start transitioning from flight plan information to ADS-based trajectory information.

a. Pre-flight clearance delivery – expected sequence of events:
1. A flight plan for the aircraft is filed with the ATC in the normal manner and any take-off slot information has been obtained as required (by the AOC). AOC has prepared an operational flight plan for the flight crew.
2. The crew checks out the operational flight plan by downloading it over datalink or gatelink, then using the FMS to generate a trajectory from the operational flight plan and ATIS using information such as the slot information, the forecast meteorological conditions, weight and balance information, take-off runway, SID.
3. The crew requests clearance for the flight from ATC via datalink.

4. The ATC reviews the flight plan and determines whether there will be any conflict with other traffic within the sectors along the route (e.g. CFMU query).
5. If required, the ATC adds constraints to the flight plan by datalink, but without sophisticated tools, so simple (i.e. in terms of slot changes) and provides these additional constraints to the flight crew as part of the departure clearance. The departure clearance contains at least the clearance limit (e.g. destination), take-off runway, SID and estimated time of departure (ETD).
6. The clearance and modifications are displayed automatically by the FMS for the flight crew to re-generate the trajectory, accept, and automatically acknowledge to ATC.

b. Ready for start-up in pre-flight – expected sequence of events is:
1. Flight crew reports ready for start-up either by voice or by datalink and, if needed, the trajectory is automatically requested by ATC via datalink.
2. CFMU performs a refined full flight flow planning.
3. ATC freezes ground movement and departure planning, resulting amongst others in an accurate ETD.
4. ATC informs flight crew of refined ETD via datalink to the FMS.
5. Flight crew accepts displayed ETD and re-generates the trajectory.

c. In-flight strategic clearance (initial/extension either after take-off or when nearing existing clearance limit) – expected sequence of events is:
1. (Optional) Flight crew request a strategic clearance extension via voice or datalink.
2. ATC issues an initial strategic clearance or an extension of the existing strategic clearance, i.e. cleared to a point on the flight plan where the path to that point is as defined by the flight plan (as modified by ATC) via datalink to FMS.
3. Flight crew normally accepts strategic clearance displayed by FMS.

d. In-flight for flight crew initiated modifications – expected sequence of events is:
1. Flight crew modifies route and/or constraints, FMS regenerates a proposed trajectory and subsequently the flight crew reviews it.
2. Flight crew requests (verbally or via downlink of proposed trajectory) route modification or another flight level together with the reason for the request (e.g. due to turbulence).
3. ATC reviews requested modifications and a) rejects it, b) clears as requested (strategic clearance) or c) modifies routes/constraints and issues strategic clearance (including modifications) via datalink to FMS.
4. Flight crew normally accepts the clearance and the route/constraints (if necessary) displayed by the FMS, re-generates the trajectory, and activates it.

e. In-flight for ATC initiated modifications – expected sequence of events is:
1. ATC modifies route and/or constraints in order to solve conflict, to sequence aircraft and so on.
2. ATC issues strategic clearance including modified route/constraints via datalink.
3. Flight crew normally accepts the clearance and route/constraints displayed by the FMS, re-generates the trajectory, and activates it.

Note: In all cases where the crew cannot comply with ATC instructions (route modification, altitude/time constraints, strategic clearance, etc.) they will automatically send an UNABLE notification by rejecting the information displayed by the FMS and then contact ATC via voice or datalink. Rejection of ATC instructions will be very remote.

Again, it should be noted that the ATC do not get sight of the full trajectory to which the aircraft is flying, although they should have significantly better knowledge than for the Verbal Negotiation as they are expected to receive the TCPs.

Also, it is expected that the ATC have a certain level of knowledge of the performance of the aircraft and therefore, will only rarely give the crew additional or modified constraints to their flight plan that they are unable to meet.

3.3.2.6.3 Partial Negotiation

Partial Negotiation is where a dedicated data link service exists that fully supports trajectory negotiation. However, the ATC is not fully equipped to make full use of this information and so there is some degradation of the negotiation service provided.

Furthermore, intent data in the form of TCP's will be transmitted to ATC (ADS-B, ADS-C)

- whenever requested by ATC (usually for FLIPCY or to perform a new COTRAC negotiation)
- along with each flight plan modification request from the flight crew.

a. Pre-flight clearance delivery – expected sequence of events:

1. A flight plan for the aircraft is filed with the ATC in the normal manner and any take-off slot information has been obtained as required (by the AOC). AOC has prepared an operational flight plan for the flight crew.
2. The crew checks out the operational flight plan by downloading it over datalink or gatelink, then using the FMS to generate a trajectory from the operational flight plan and ATIS using information such as the slot information, the forecast meteorological conditions, weight and balance information, take-off runway, SID.
3. The crew requests clearance for the flight from ATC via datalink.
4. The ATC reviews the trajectory and determines whether there will be any conflict with other traffic within the sectors along the route (e.g. CFMU query).
5. If required, the ATC adds constraints to the trajectory, and provides these additional constraints to the flight crew as part of the departure clearance by datalink. The departure clearance contains at least the clearance limit (e.g. destination), take-off runway, SID and estimated time of departure (ETD).
6. The clearance and modifications are displayed automatically by the FMS for the flight crew to re-generate the trajectory, accept, and automatically acknowledge to ATC.

b. Ready for start-up in pre-flight – expected sequence of events is:

1. Flight crew reports ready for start-up either by voice or by datalink and, if needed, the trajectory is automatically requested by ATC via datalink.
2. CFMU performs a refined full flight flow planning.
3. ATC freezes ground movement and departure planning, resulting amongst others in an accurate ETD.
4. ATC informs flight crew of refined ETD via datalink to the FMS.
5. Flight crew accepts displayed ETD and re-generates the trajectory.

c. In-flight strategic clearance (initial/extension either after take-off or when nearing existing clearance limit) – expected sequence of events is:

1. (Optional) Flight crew request a strategic clearance extension via voice or datalink.
2. ATC issues an initial strategic clearance or an extension of the existing strategic clearance, i.e. cleared to a point on the trajectory where the path to that point is as defined by the negotiated trajectory (as modified by ATC) via datalink to FMS.
3. Flight crew normally accepts strategic clearance displayed by FMS.

d. In-flight for flight crew initiated modifications – expected sequence of events is:

1. Flight crew modifies route and/or constraints, FMS regenerates a proposed trajectory and subsequently the flight crew reviews it.
2. Flight crew requests (verbally or via downlink of proposed trajectory) route modification or another flight level together with the reason for the request (e.g. due to turbulence).
3. ATC reviews requested modifications and a) rejects it, b) clears as requested (strategic clearance) or c) modifies routes/constraints and issues strategic clearance (including modifications) via datalink to FMS.
4. Flight crew normally accepts the clearance and the route/constraints (if necessary) displayed by the FMS, re-generates the trajectory, and activates it.

e. In-flight for ATC initiated modifications – expected sequence of events is:
1. ATC modifies route and/or constraints in order to solve conflict, to sequence aircraft and so on.
2. ATC issues strategic clearance including modified route/constraints via datalink.
3. Flight crew normally accepts the clearance and route/constraints displayed by the FMS, re-generates the trajectory, and activates it.

Note: In all cases where the crew cannot comply with ATC instructions (route modification, altitude/time constraints, strategic clearance, etc.) they will automatically send an UNABLE notification by rejecting the information displayed by the FMS and then contact ATC via voice or datalink. Rejection of ATC instructions will be very remote.

In this case the ATC has good knowledge of the trajectory that the aircraft is intending to fly. However, the ATC is unable to use that information fully within their planning system. Even so, it is expected that the ATC will only very rarely give the crew additional or modified constraints to their trajectory that they are unable to meet.

3.3.2.6.4 Full Negotiation

Full Negotiation is where a dedicated data link service exists that fully supports trajectory negotiation and the ATC is fully equipped to make full use of trajectory information provided by the aircraft in the negotiation process.

The same sequence is again followed, the main difference compared to basic negotiation is that intent data in the form of detailed trajectories instead of TCP's are downlinked. This means that the basis for air traffic control will no longer be the flight plan but the agreed-upon trajectory, although this depends on the ATC tools available on the ground.

In this case, the understanding of both the ATC and the crew with respect to the trajectory that the aircraft is expected to fly is the same. Also, with the support of the tools and the ability to fully utilise the trajectory information within the planning system, it is expected that the ATC will never provide constraints to the crew that the aircraft cannot meet. However, if this does ever happen, both the data link and the voice communication will allow communication of the problem and its resolution.

3.3.2.7. Application Time Constraints

The negotiation process will be dependent on the response time of the data link, the ATC and crew. However, it is not anticipated that the negotiation process should be time critical. If the Trajectory Negotiation fails to complete within the required time and/or the aircraft flies outside its clearance, then the FMS will continue to command the aircraft along its active trajectory, which was generated according to the filed flight plan or as modified and sent to the ground during the previous negotiation process, until the crew resolve the problem. A procedure needs to be developed that handles this abnormal situation.

Due to the interactive nature of the application, time constraints are required to bound the response times from the crew and ATC. It is anticipated that these constraints will be covered by the definition of the COTRAC service (as part of the ODIAC services).

3.3.2.8. Information Exchanges

Additional information will be required between the crew and the ATC with respect to the trajectory (including TCPs and TPs) and the ATC constraints. The level of trajectory and constraint information provided will depend upon the level of Trajectory Negotiation service.

For the trajectory, the maximum amount of information provided will be :-

Longitude
Latitude Altitude
Time
Flight Phase

Where Flight Phase will contain :-
Aircraft Configuration
Target Conditions
Exit Conditions

For the constraint information, the maximum amount of information provided will be :-
Longitude
Latitude
Place Bearing Distance
Place Bearing Place Bearing
Waypoint Identifier
Altitude Window
Speed Window
Time Window
Airspace Type

For the clearance information, the maximum amount of information provided will be:
Published Identifier
Latitude
Longitude
ATS Route Designator
Along Track Waypoint
Reporting Point

3.3.2.9. Exception Handling
Failure to obtain successful trajectory negotiation, either due to complete failure of equipment or due to lack of time (resulting in ATC needing to perform immediate conflict resolution), will require the reversion of the system to tactical control.

With the data link applications, a limited subset can be provided over voice if the data link fails, however, the complexity will have to be significantly reduced. (It is always expected that voice communication with the ATC will be available.)

3.3.2.10 Additional Operation Information

3.3.2.10.1 Types of Clearances
Trajectory Negotiation only supports strategic clearances. During Tactical and some types of Partial Delegation (such as level-flight/in-descent station keeping) and Full Delegation, Trajectory Negotiation can only support the negotiation of a later strategic clearance. As a result, the Trajectory Negotiation function will change depending upon clearance type, which in turn has a dependence on the type of airspace.

See the Trajectory Navigation section on Operation At Mode Transitions for a description of operational scenarios involving clearances during mode transitions.

3.4 Precision approach

3.4.1 Operation Service Description

A means to enable aircraft to land at their chosen destination whatever the weather is a prime aviation requirement. Traditionally, due to the employment of different technologies, there has been two distinct methods, Precision Approaches (PA) and Non-Precision Approaches (NPA).

Today's ATC system provides electronic aids and procedures for both PA and NPA. With the advent of accurate long range navigation by satellite, the distinction between these two categories is beginning to blur, and new categories are being developed. Thus this chapter shall only refer to PA. The technology and procedures are outlined as the **Precision Approach** application.

PA throughput is ultimately limited by wake vortex considerations. Controllers separate aircraft aircraft on the Final Approach Track (FAT) allowing for wake vortex, and must allow for positioning inaccuracy. A more accurate means of positioning will permit this allowance for inaccuracy to be reduced. Two GPS enhancements, Satellite-Based Augmentation Systems (SBAS) and Ground-Based Augmentation Systems (GBAS), will support this enhanced positioning accuracy, and will provide additional benefits.

The instrument landing system (ILS) has been the almost exclusive aid to enable PA for the last 40 years. Other terrestrial navigation aids, such as NDB, VOR and DME have been used for NPA. The limitations of this technology have determined the associated PA procedures, with those for NPA being much more complex than those for PA. The advent of SBAS/GBAS will permit the use of more simple approach procedures, causing the complex NPA procedures to no longer be required. SBAS procedures and airborne equipment (The Minimum Operation Performance Specifications for Global Positioning System/Wide Area Augmentation System Airborne Equipment is given by RTCA/DO-229B, October 6, 1999) will not be validated by MA-AFAS, as this work has already been done.

The ILS PA procedures are well-established. A first step for the PA application will be to fly the ILS procedures in the same manner as usual, but the technology used to provide course deviation information will be transparent to the pilot, and will be GBAS rather than ILS.

GBAS is primarily a navigation application, which is an ICAO standardised system with complete Standards and Recommended Practises (SARPS). It is part of the ICAO Global Strategy for transition to GNSS, and is complementary to SBAS. It enables enhanced positioning accuracy and provides integrity information throughout the local area (up to 20 miles from the ground transmitter). ICAO are developing standards to use GBAS {Position, Velocity, Time} at extended ranges (up to 120 miles) in order to provide regional navigation and facilitate curved approaches.

GBAS consists of three elements. Data from a Ground Subsystem is used to compute corrections and integrity data for satellites in view. A VHF Data Broadcast (VDB) then sends these corrections and integrity information. The VDB includes details of approaches supported, and the level of service available. The Aircraft Subsystem uses the ground-derived data to generate approach guidance and integrity flags. Specifications for the airborne subsystem can be found in Minimum Operation Performance Specifications for Global Positioning System/Local Area Augmentation System Airborne Equipment is given by RTCA/DO-253, January 11th, 2000.

All of the equipment required on the ground is co-located, close to the approach(es) of interest.
GBAS has been designed as an ILS look-alike in order to minimise the certification effort. It is expected that GBAS will replace ILS where the ILS is suffering interference or where a GBAS installation is cost-beneficial. It also has other benefits:

- it supports approaches to multiple runway ends (and possibly multiple airports)
- It not only provides an approach capability to runway ends where previously there was no capability, but also the maintenance costs can be shared
- Less siting restrictions than ILS/MLS
- The VHF link providing the signal in space will have a Communication aspect, as there is spare capacity to provide new services.

Some systems (Special Cat I) are already in operation, but systems fully compliant with international standards will be available in the United States in late 2002, and in Europe shortly afterwards. However, Europe has more of a requirement for Cat III (autoland), which will require further development. Initially, these will support Cat I, but eventually the systems are expected to be able to support Cat III

GBAS will also support new approach procedures using curved paths to minimise environmental impact and maximise safety.

To conduct this operation, only the aircraft performing the approach need be equipped. Use of GBAS does not require other aircraft to be equipped. Controllers are unlikely to be affected by GBAS deployment, as the controller pilot interaction is likely to be the same as it is now (although there may be scope for datalink transactions at a later date). No new actions by the controllers are required, and they do not need to be informed about equippage.

The deployment of GBAS does require either the airport or ATSP to invest in the installation and operation of the ground equipment. Thus deployment is likely to take place on a case by case basis, subject to cost benefit analysis.

3.4.2 Scope and Objective

Both SBAS and GBAS were designed for the approach phase of flight, in order to meet the most demanding requirements. The degree to which a precision approach can be supported is determined by the expected performance. It is envisaged that SBAS will be able to support precision approach operations down to near-Cat I (in addition to en-route RNAV), whereas GBAS will support Cat IIIc (autoland). However, as both SBAS and GBAS provide positioning information, they are suitable for all phases of flight.

The service provided will give the ability to approach an adequately-equipped airfield in poor meteorological conditions.

For SBAS, it is likely that production instruments will incorporate a moving map display. The approach displays may also deviate from supporting the “cross-hairs” indicator, replacing it with a flight director.

The purpose of implementing SBAS is to provide high performance RNAV navigation, and a degree of precision approach capability over a wide area. The provision of high performance navigation will allow restructuring of ground navaids, giving gains in efficiency, and will provide this high performance where previously no capability was available. The provision of a degree of precision approach capability will allow approach procedures to be available where previously there was none, it will allow complex and unsafe non-precision approach procedures to be replaced by new, simpler approaches, and it will allow the restructuring of ground approach aids, some of which are limited by interference, giving gains in efficiency.

The purpose of implementing GBAS is to primarily provide precision approach capability up to autoland, replacing current ground-based units that are suffering from interference, and providing the capability where previously none existed. One GBAS unit provides precision approach capability for the surrounding region, and thus efficiencies will be made with existing precision approach aids, which require one installation per runway end. GBAS will also provide high performance RNAV in the surrounding region.

There are likely to be 2 equipage options. The Multi-Mode Receiver (MMR) (specified in ARINC 755-1) will provide a PA capability, but the technology used to do this will be transparent to the pilot and the flight control system (FMS). The cockpit instrumentation will remain as used today, with the only output from the MMR being course deviation. Also, there will be GNSS Navigation and Landing Unit (GNLU) (ARINC 756-2), which will provide the increased information available when using GNSS to the pilot and the FMS. This method of coupling to the FMS requires considerable developemnt of the FMS. For the validation exercise, it is expected that the course deviations will be provided, with some of the additional information (Position Velocity and Time (PVT)) also provided to enable FMS development.

These applications will be validated to minima comparable to Cat I only, and therefore autoland will not be validated.

The operational objective of PA by GBAS deployment is to replace ILS installations, and provide PA capability where previously it was not available. To reduce the separation standards is not an objective of this application. Nevertheless, the application results could be used to further investigation into separation reduction. To provide accurate positioining to enable RNAV in the Terminal Manoeuvring Area (TMA) is also not an objective, but this benefit may also occur due to the coverage area.

3.4.3 Expected Benefits and Anticipated Constraints

The primary benefit of this application is that, by using existing ILS procedures, it will be possible to exploit the technology at the earliest opportunity to permit the long-awaited ILS replacement.

PA by GBAS is expected to show accuracy (consistency) improvements for the critical approach phase. Improved accuracy increases safety. Improved 4D accuracy will also permit throughput to be maintained, and the approach capacity maximised.

An ILS installation is capable of serving a single runway end. However, a single GBAS ground station is expected to be able to support PA to all runway ends at an airport, and even to runway ends at other airports in the vicinity, usingthe same VDB frequency. A major benefit to users will be that there will be PA capability at runways to which there previously was none. Also the costs of an installation will be shared between more runways.

The technology of an ILS requires that it is re-calibrated at regular intervals. This maintenance cost is expected to be considerably lower for a GBAS unit.

The GBAS ground sub-system is not subject to the same stringent siting limitations as ILS and MLS.

Further benefits may prove to be increased throughput due to increased position certainty, and the support of new approach procedures that will improve safety and environmental impact.

A constraint is that GBAS requires the continued provision of the GPS. However, no break in service provision is expected. A further constraint is that full exploitation of curved approaches by GBAS requires the development of new approach procedures. However, criteria for procedure design is still under discussion, and the development of procedures will take time.

3.4.4 Human Factors

Human factors considerations for GBAS are stated in Appendix G Operational Concept for Landing Systems using LAAS in the Minimum Aviation Standards for the Local Area Augmentation System (LAAS), RTCA DO-245, where LAAS is the U.S. implementation of GBAS.

GBAS has been designed to be similar in function to ILS. Ths means that flight crew will be able to use the GBAS with operations conforming to current ILS operations. This minimizes the training required to fly procedures using the GBAS system. However, training will still be required for selection of the correct procedure, recognition of the levels of service available, and the significance of alerts.

In the future aircrew will need to be trained about curved procedures, and how to interpret the HMI. Whilst curved approaches have been flown using ILS-style needles, the limitations of this HMI are recognised. Curved approaches will not be performed using GBAS for this project. Here, SBAS will be used for the curved path, transitioning to GBAS for the Final Approach Track. The human factors issues involved in this transition will be investigated.

The impact on the flight deck instrumentation is expected to be minimal, as both the GNLU and MMR will be used to drive the same displays as used when performing PA with ILS. When performing a PA, aircrew will still be required to refer to a copy of the approach template, in order to set speeds and rate of descent etc., in the same way as doen today. However, the GNLU specification does permit new information to be made available, which will help with the task of performing a precision approach. This additional information may be displayed by a two line text display or it displayed graphically.

At least initially, the system will remain independent of other aircraft systems. In the future, aircrew will need to be trained in the methods used to couple the GNLU to the FMS.

The procedures required for transition from SBAS to GBAS are the subject of a separate study.

3.4.5 Operating Method Without Operation Application

Without PA via GBAS, precision approach is conducted by ILS. For those runways using ILS to provide a PA capability, ICAO Doc.s 4444 Procedures for Air Navigation – Rules of the Air (PANS RAC) and 8186 Procedures for Air Navigation – Operations (PANS OPS) give a full description, and define the categories of approach. From these documents it can be seen that a PA is a wholly separate procedure, and was performed using the instructions and template published for each aerodrome in the Aeronautical Information Publication (AIP). The appropriate VHF frequency for the ILS is selected, and then the theoretical approach track approached from the underneath to avoid capture of a reflection of the glidepath beam. Once the localiser and glideslope have been captured, the needles of a cross-pointer indicator are then kept as central as possible, with centred needles indicating that the aircraft was on the theoretical approach path.

The path to the PA procedure maybe via a Standard Arrival Route (STAR) (managed by Approach Control), or by Approach Control radar vectors. Separation on the final approach segment is determined by the controllers, but may be substantially above the separation minima due to the limited radar spatial resolution and margin caused by time to update.

3.4.6 Operating Method With Operation Application

MA-AFAS has broken the PA theme into 3 parts (based on the functions identified in WP1.3 deliverable D13):

- GBAS for ILS-like Straight Line Precision Approaches
- Guidance for Curved Precision Approach
- Guidance for Curved Departure

For *GBAS for ILS-like Straight Line Precision Approaches*, the operating method is similar to that without the application, as the change to using GBAS instead of ILS is almost transparent to both the controller and pilot.

The exact method to be adopted by the pilot will depend upon the airborne equipment installed, i.e. whether GNLU or MMR, e.g. for the PA by GBAS using the MMR, the alerts will be given by the NAV flag on the ILS cross-pointer indicator. ARINC 756 details the alerts available when using a GNLU as the airborne subsystem. Details of the GBAS performance type, Lateral Guidance only use, and RNAV use are given in Appendix G of DO-245. DO-245 also gives the requirements for the GBAS to support operations including Cat I, II, III PA and landings. Aircrew will not have to fly special procedures to capture the ILS beams. Initial HMIs may adopt the ILS needles as a means of providing guidance information to the pilot. However, other better interfaces (e.g. a flight director) will become prevalent.

The coverage of the GBAS means that there may be many more instrument approaches available. Thus there is an approach selection scheme that makes use of 5 figure identifiers, rather than selecting the radio frequency of the navigation aid directly.

However, for future aircraft and future operations (i.e. curved approaches using GBAS), new criteria may be developed to take advantage of the unique benefits of a precise satellite-based navigation system.

For *Guidance for Curved Precision Approach/Departure*, the operating method for controllers will differ. RNAV-equipped aircraft will enable less radar vectors to be given, reducing controller workload. Aircraft will be able to fly accurate RNAV tracks in the TMA, making more efficient use of airspace. Flight director symbology will enable these tracks to be flown accurately. At a given point, the guidance will change from being provided by the SBAS to the GBAS. This may be automatic, and thus invisible to the pilot.

3.4.7 Application Time Constraints

Not applicable.

3.4.8 Single Transaction Scenario

Not applicable.

3.4.9 Information Exchanges

The operator of the GBAS ground subsystem will input the exact geodetic co-ordinates of the ground subsystem antenna, to enable the differential calculations to be calculated. The operator will also input the approach procedures.

The information exchange involved with GBAS ground station and airborne equipment is one way. Details of the message types and data content are given in ED-95 and DO-245.

The information exchange involved with the GBAS airborne equipment and other aircraft systems will be determined by the choice of airborne equipment:

The MMR GBAS airborne equipment will provide course deviation and status information suitable for display by an ILS cross pointer indicator and its Navigation Valid flag. This information will also be available for use by the FMS.

The GNLU GBAS airborne equipment will provide the above information, and will also make PVT information available to the FMS, and possibly the Navigation Display in the cockpit.

No ICD is included in this document. Details of the MMR and GNLU are given by ARINC 755 and 756 respectively.

Information exchanges between the pilot and controller will remain similar to those used for current operations.

3.4.10 Exception Handling

A primary feature of GBAS is that it provides integrity for the application. This augmentation therefore provides assurance that the GPS is able to support the required level of performance.

The cockpit display will notify if GPS is not able to support the application, or one of the subsystems has failed. In the same way as when an ILS becomes unserviceable, the aircraft will notify ATC, and then need to divert or find a different means to aid an approach.

3.5 AOC

The Airline Operation Centre will play an important pre-flight management, in-flight support and post-flight analysis role. To fulfil these roles, under MA-AFAS, the following functions have been selected:

- Improved Communication (ie Upgraded Aircraft / AOC Data Link)
- Improved Fleet Management and Operational Control
- Improved Meteorological Data
- Collaborative Decision Making (CDM)

The overall aims of the AOC implementation within MA-AFAS are:

- To show that existing AOC functions can be supported by the MA-AFAS architecture/infrastructure
- To demonstrate new AOC functions enabled by MA-AFAS-specific services.

3.5.1 AOC Communication

Currently AOC have limited data link communication with their aircraft, provided by ACARS. Unfortunately, service demand outstrips capacity, affecting the ability to successfully transmit and receive a message. Therefore, in order to maintain an acceptable level of service, an alternative means of data link communication is required. Two approaches are being considered under MA-AFAS and these are:

- Using GACS over ATN data link transferred by ARINC or SITA network on the ground
- Using a non-ATN data link transferred by a standard internet service provider on the ground

3.5.2 ATN Compliant AOC Communication

3.5.2.1. Operation Service Description

Modern AOCs require data link communication with their aircraft throughout their operation in order to perform effective fleet management and obtain fast turn around times. ATN is being developed primarily for Air Traffic Control, but provides facilities for other customised classes of communication (to replace communication services such as ACARS). Different AOCs operate in significantly different ways, and so a standard set of applications do not exist for AOC. To simplify the process of defining ATN applications for AOC, and to support existing legacy applications, a generic service interface has been developed (called Generic Application Communication Service (GACS)). This service will then provide the interface to the applications running on the aircraft and in the AOC. The data will be transmitted over a ground network (such as that provided by ARINC and SITA) from the AOC and then via VHF digital link or SATCOM to the aircraft. Similarly, the aircraft will transmit the data via VDL or SATCOM which will be routed to the ground network and then to the AOC.

3.5.2.2. Scope and Objective

This service will be used throughout the flight. As gatelink is not an integral part, it is assumed that AOC communication will not be possible at the gate, but should be available during taxiing and throughout the flight.

This service will enable AOC data communications with aircraft. This will support the AOC reception of aircraft system information, including maintenance, flight plan and status information, and will allow the crew to request information on weather, alternates, etc or compose their own messages.

3.5.2.3. Expected Benefits and Anticipated Constraints

3.5.2.3.1 Expected Benefits

As with ACARS, this datalink means that the aircraft can remain in contact with the AOC throughout the flight.

The reliability of the data (covering its timeliness and data content) will be significantly better than the previous ACARS, due to extra network services and error checking provided by ATN.

The capacity of the network will be increased as this service will be supplemental to ACARS, so reducing the existing load on ACARS.

The service is based on avionics equipment that is expected to be required for ATC communication and therefore, no extra equipment is required in the aircraft to provide the AOC data link capability. Only software upgrades are required.
Incentive schemes are likely to be put in place by the ground network providers to try to get their customers to switch to ATN. Therefore, initially, there should be significant cost saving on the messages.

3.5.2.3.2 Anticipated Constraints
The main disadvantage is expected to be the cost of the Datalink Service Provider charges. Although there are no commercial ATN services in operation yet, the charges are expected to be comparable to existing ACARS charges. For services charged by the size of message, it is difficult to determine whether the use of ATN represents an advantage or a disadvantage. Although the ATN has no restriction on the format of messages, and so the messages can be sent in the most compact form possible, this is offset by the extra header and protocol control information required.
It is currently unclear whether the bandwidth of ATN will be sufficient to cover all the AOC datalink service demands, as demand from the airlines is increasing. While the bandwidth of ATN is likely to be an order of magnitude greater than present generation ACARS, the principal use of ATN will be for ATC application traffic, with AOC traffic given lower priority. It is therefore difficult to predict whether the ATN Quality of Service will meet AOC expectations.

3.5.2.4. Human Factors
The human factor considerations need to cover the notification and management of the status of the communications. This includes such items as acknowlegement of receipt for messages, and notification of unexpected loss of connection. Suitable interfaces need to be provided for the AOC operator and the aircrew to manage the ATN communications.

3.5.2.5. Operating Method Without Operation Application
The current operating procedures would be using ACARS as the data link service. This is slow and unreliable but will allow the aircraft to remain in contact with the AOC throughout its flight. It requires ground infrastructure to link the aircraft to the AOC (whether SATCOM or VHF transmission is used) which is currently provided by ARINC or SITA. To access this network, the AOC must have a suitable terminal within their operation centre that links to this ground network.

3.5.2.6. Operating Method With Operation Application
Operating with the application, depending upon the implementation, could appear no different to that of using ACARS. To gain maximum benefit, it is expected that message sets will be enhanced, requesting more information of which more can be time critical due to the upgraded datalink service.

3.5.2.7. Application Time Constraints
The message handling facility at the current time is not time critical. However, more benefit could be derived from the data link if the AOC could obtain regular and reliable communication with the aircraft, where aircraft data could then be used to support new applications such as CDM and for real time monitoring of the aircraft systems by the AOC.

3.5.2.8. Information Exchanges
The exact format of the data will be tailored to each individual AOC needs. As a result, the volume and content of the data will vary from airline to airline.

3.5.2.9. Exception Handling
No exception handling will be required for non-time critical AOC datalink communication. In this case, the failure of the AOC datalink will not affect the safety of the flight, but could affect the efficiency of the AOC fleet management. The introduction of time-critical AOC communications could change this situation. In this case, the design of the new applications (and the procedures for their use) must be such that a failure in communications will not affect the safety of the flight.

3.5.3 Non-ATN Compliant AOC Communication

3.5.3.1. Operation Service Description

Modern AOCs require data link communication with their aircraft throughout their operation in order to perform effective fleet management and obtain fast turn around times. Many technologies are becoming available that could provide the AOC with opportunities for relatively cheap communication with their aircraft during flight. Combinations proposed are use of SATCOM and VDL Mode 4 which then link to a ground station, where this ground station is connected to the internet. The information is then encrypted and sent across the internet to the AOC.

Depending upon the network facilities provided by the internet service provider and the capability of the ground station, the routing of the message to the aircraft could be handled by either:

- AOC, if no facilities are provided
- Internet Service provider, if the ground stations identify which aircraft are logged into them

The aim of this service is to provide flexibility in choice and so keeping cost low. The ground stations would have to be either existing (so renting time for their use, e.g. renting spare capacity from ATC ground stations) or set up by a consortium of airlines (so a part (or total) ownership scheme). For provision of the ground/ground internet service, there are many competing companies that could cheaply provide this service.

It is assumed that the quality of the service required by the AOC is not high as otherwise it would be anticipated that the AOC would chose the ATN solution for AOC communication. As a result the ratio of data content to message size is higher, but the time sequence of the messages cannot be guaranteed, nor the maximum time that the message will take to reach the recipient.

3.5.3.2. Scope and Objective

This service will be used throughout the flight. As gatelink is not an integral part, it is assumed that AOC communication will not be possible at the gate, but should be available during taxiing and throughout the flight.

This service will enable AOC data communications with aircraft. This will support AOC reception of aircraft system information, including maintenance, flight plan and status information, and will allow the crew to request information on weather, alternates, etc or compose their own messages.

3.5.3.3. Expected Benefits and Anticipated Constraints

3.5.3.3.1 Expected Benefits

As with ACARS, this datalink means that the aircraft can remain in contact with the AOC throughout the flight.

The capacity of the network will be increased as this service will be supplemental to ACARS, so reducing the existing load on ACARS. It will also be more controllable by the airlines and therefore should be more tailored to their needs.

The AOC data link does not require communication equipment dedicated to the AOC communication within the aircraft. Existing SATCOM equipment can be used for the service, as well as VDL Mode 4 transceivers (which would have been fitted for surveillance (i.e. ADS-B)). However, with the VDL Mode 4 equipment, integrity and availability issues would have to be addressed to ensure that the communication would not interfere with the main purpose of the equipment. (Note that if a VDL Mode 4 transceiver were being used for ADS-B for ATC surveillance purposes, the ADS-B ground stations would have to be used for the AOC service also).

No one ground service provider will dominate. The selection of potential candidates is high and therefore, a cheap and customer-focused service should be easily obtainable. If the AOC was unhappy with the service provided by a particular internet service provider, then the AOC would be readily able to change the provider. The AOC would also have the flexibility to negotiate its charging policy for the messages (ie size of message, period of usage, fix rental etc).

3.5.3.3.2 Anticipated Constraints

The quality of the service will not be high. It is expected that the quality will be at the same level as that currently provided by ACARS. This means any time critical data cannot be sent via this data link communication service.
The geographic extent of the network could be an issue for VDL Mode 4; a consortium looking to establish a ground station network would have to obtain VHF channels to use for the service, ideally using the same frequency over a large geographic area (to minimise handover problems). Coverage over a large area would require a large number of ground stations, with correspondingly high procurement and maintenance charges. A network with limited geographic scope would require alternative services for communications out of coverage, thereby increasing the complexity of the communications service.

3.5.3.4. Human Factors
As mentioned above, the human factor considerations need to cover the notification and management of the status of the communications. This could include such items as acknowlegement of receipt for messages, and notification of unexpected loss of service (dependent upon the criticality of the particular message(s)). Suitable interfaces need to be provided for the AOC operator and the aircrew to manage the non-ATN communications.

3.5.3.5. Operating Method Without Operation Application
As stated above, the current operating procedures use ACARS as the data link service. This is slow and unreliable but will allow the aircraft to remain in contact with the AOC throughout its flight. It requires ground infrastructure to link the aircraft to the AOC (whether SATCOM or VHF transmission is used) which is currently provided by ARINC or SITA. To access this network, the AOC must have a suitable terminal within their operation centre that links to this ground network.

3.5.3.6. Operating Method With Operation Application
Operating with the application, depending upon the implementation, could appear no different to that of using ACARS.

3.5.3.7. Application Time Constraints
The message handling facility at the current time is not time critical. This is consistent with the quality of service expected to be provided by this service.

3.5.3.8. Information Exchanges
The exact format of the data will be tailored to each individual AOC needs. As a result, the volume and content of the data will vary from airline to airline.

3.5.3.9. Exception Handling
No exception handling will be required for AOC datalink communication. The failure of the AOC datalink will not affect the safety of the flight, but could affect the efficiency of the AOC fleet management.

3.5.4 Fleet Management

3.5.4.1. Operation Service Description
Fleet management refers to a range of actions that AOCs use to optimise their operations. Three specific functions are considered in the MA-AFAS context, as follows:

- Trajectory Planning
- Flight Progress Monitoring
- Aircraft Systems Information

Trajectory planning is the core function of any airline operation. The optimal plan for the flight takes account of many factors, including routing options, forecast weather, payload, fuel load, crew scheduling, and aircraft availability and equipment. The plan is filed with the relevant ATS providers. The plan is also provided to the aircrew; currently, this may be ACARS (if the aircraft is so equipped), but more usually a hard copy is handed to the crew by a dispatcher at the gate. Any subsequent change to the influencing factors will potentially change the optimal plan for the flight. Without datalink capability, it is difficult (if not impossible) to communicate the desired plan changes to the flight crew once the aircraft has taken off. Datalink provides the possibility for AOC to influence the flight trajectory throughout the duration of the flight, in order to optimise its overall operations, and also for the aircraft to report any ATC-initiated trajectory changes.

One of the key inputs to the trajectory planning is aircraft location, both present and future (estimated). The flight progress monitoring function provides this information. ACARS provides a limited set of messages that can be used for these purposes, specifically the Out, Off, On, In (OOOI) messages, position reports and ETA. An improved datalink communications capability offers the possibility of more frequent reports.

The Aircraft Systems Information function provides maintenance data for particular aircraft. The datalink communications system is used to collect information including engine takeoff reports, snag reports and Aircraft Condition Monitoring System (ACMS) reports.

3.5.4.2. Scope and Objective

This service will be used throughout the flight. As gatelink is not an integral part, it is assumed that AOC communication will not be possible at the gate, but should be available during taxiing and throughout the flight.

3.5.4.3. Expected Benefits and Anticipated Constraints

3.5.4.3.1 Expected Benefits

As with ACARS, the service will allow AOC to exercise greater control over its fleet operations, and present greater opportunities to optimise operations, by:

- continuing to refine planned trajectory throughout the flight
- monitoring flight progress in more detail
- obtaining early indications of aircraft systems faults.

Depending on the underlying communications service, the message dialogues may be more reliable than their ACARS equivalents.

3.5.4.3.2 Anticipated Constraints

There are no anticipated constraints specific to the fleet management applications, however, the constraints relating to the underlying communications function(s) still apply.

3.5.4.4. Human Factors

The human factor considerations need to cover the generating and sending of a message as well as message notification. Message generation will be required to be either generated from scratch (i.e. Free Text) or generated from a structured list (i.e. from predefined message formats). Therefore suitable interfaces need to be provided for the AOC operator and the aircrew to compose these messages. Also, particularly on the aircraft, suitable notification of a new message is required for any messages that require a response.

3.5.4.5. Operating Method Without Operation Application

The current operating procedures would be using ACARS as the data link service, with the limitations and disadvantages noted above. For aircraft not fitted with ACARS, voice reports would have to be used; where even this is not possible, there is no communication possible in-flight.

3.5.4.6. Operating Method With Operation Application

Operating with the application, depending upon the implementation, could appear no different to that of using ACARS. Any differences would be likely to be related to the data format and/or the frequency of transmission.

3.5.4.7. Application Time Constraints

Fleet management and operational control functions as described here are not time critical.

3.5.4.8. Information Exchanges

The exact format of the data will be tailored to each individual AOC needs. As a result, the volume and content of the data will vary from airline to airline.

3.5.4.9. Exception Handling

No exception handling will be required for AOC datalink communication. The failure of the AOC datalink will not affect the safety of the flight, but could affect the efficiency of the AOC fleet management.

3.5.5 Meteorological Data

3.5.5.1. Operation Service Description

An accurate knowledge of weather information is essential to optimisation of airline operations. Forecast data is used in trajectory planning, where using favourable winds can result in significant fuel savings. Graphical representation of forecasts could also be provided (weather display), providing a visual indication of the forecast for the aircrew to interpret. Notifications of specific weather events, such as airport low visibility or snow operations, or the presence of areas of bad weather are used in-flight to modify the plan. The use of datalink communications to exchange weather data between AOC and the aircraft will provide further opportunities to optimise operations.

3.5.5.2. Scope and Objective

This service will be used throughout the flight. As gatelink is not an integral part, it is assumed that AOC communication will not be possible at the gate, but should be available during taxiing and throughout the flight.

This service will allow AOC to provide updated weather information to the flight, to support other planning functions.

3.5.5.3. Expected Benefits and Anticipated Constraints

3.5.5.3.1 Expected Benefits

Providing updated forecast data to the aircraft will allow trajectories to be calculated more accurately on the aircraft. The provision of a weather display will allow the aircrew to assess for themselves the conditions likely to be encountered during the flight. This information, together with timely notification of other weather events, will allow the aircrew to evaluate or propose changes to the current flight plan.

3.5.5.3.2 Anticipated Constraints

The principal constraint on the uplink of meteo forecast data will be the availability of bandwidth on the data link. Forecast weather messages may be very large, depending upon the format of the data, and the scale of the area and time period for which the forecast is provided. The uplink of weather information may therefore be correspondingly prohibitively expensive. The aim will therefore be to define a balance between minimising the amount and frequency of data transmitted and providing sufficient information for the aircrew to identify options to optimise the flight plan.

Notification of weather event messages are expected to be relatively short and therefore not present such a problem.

3.5.5.4. Human Factors

The human factor considerations need to cover message notification and display, and potentially also the generating and sending of a message. If the application as defined allows the pilot to request meteo information, suitable interfaces need to be provided for the aircrew to compose these messages.

3.5.5.5. Operating Method Without Operation Application

There are limited graphical weather services offered by ACARS providers. Otherwise, the responsibility for informing aircraft of significant weather (en-route and ATIS) rests with ATC. ACARS may also be used for AOC to pass on weather event notifications.

3.5.5.6. Operating Method With Operation Application

Operating with the application would require AOC to identify when updated forecast information should be provided to the aircraft. The information provided would be tailored to the aircraft's planned trajectory.

When new meteorological information is received by the flight crew, they would normally re-generate the trajectory to assess the impact on their flight. If the impact requires changes to negotiated constraints, the crew will initiate a negotiation with ATC to obtain a new clearance. If the trajectory can be optimised without impact on the negotiated constraints, then the crew can adopt the new trajectory without re-negotiation. See section 3.3.2.6 for details of re-negotiation.

3.5.5.7. Application Time Constraints

The meteorological data function is not time-critical.

3.5.5.8. Information Exchanges

As described above, the content and presentation of forecast data can be defined in a number of ways. The volume and content of the data will vary from airline to airline.

3.5.5.9. Exception Handling

No exception handling will be required for AOC datalink communication. The failure of the AOC datalink will not affect the safety of the flight, but could affect the efficiency of the AOC fleet management.

3.5.6 Collaborative Decision Making

3.5.6.1. Operation Service Description

The term Collaborative Decision Making (CDM) refers to a set of techniques and applications by which the collective requirements of all airspace users can be taken into account in the ATM process. In the MA-AFAS context, the CDM application refers to In-Flight Traffic Management. This covers planning while a flight is airborne, but outside the timeframe considered by a planning controller (say at least 10 minutes before sector entry). The concept is to implement a dialogue between AOC and the pilot to exchange information such that optimisations to the flight plan can be identified and agreed; when agreed, the change is proposed to ATC (by AOC or the pilot).

3.5.6.2. Scope and Objective

The objective is to take advantage of increased flexibility of use airspace, free routing, and improved trajectory prediction to optimise flight performance as early as possible. The greatest potential for taking decisions with a medium- to long-term impact on the performance of the flight exists in the en-route phase of flight. However, as the application presupposes at least a 10-minute lead before sector entry, the service may be in use from before take-off to shortly before landing.

3.5.6.3. Expected Benefits and Anticipated Constraints

3.5.6.3.1 Expected Benefits

The principal benefit for AOC is the ability to modify flight plans at a stage where significant cost savings may be achievable. This involves being able to react to events, such as the early opening of reserved airspace, or the identification of bad weather areas, in a timely manner.

3.5.6.3.2 Anticipated Constraints

The ultimate responsibility for approval of flight plan changes rests with ATC, and this would have to include co-ordinating and reconciling potentially conflicting requests from all parties involved, i.e. downstream ATC, airport authorities and other airlines. This represents an increased workload, primarily for ATC, but also for the other parties involved.

This application also implicitly requires ATC and AOC to share a uniform view of the airspace and traffic situation over a large area, including flow and traffic density information. This may be achieved by providing access for AOCs to a harmonised distributed database containing in-flight planning information for the participating ATCCs. This scenario raises a number of issues, including the potential sensitivity of the database information, the arrangements for distribution, the upgrading of AOC systems to use the information, and so on.

3.5.6.4. Human Factors

The human factor considerations need to cover the generating and sending of a message as well as message notification. Message generation will be required to be either generated from scratch (ie Free Text) or generated from a structured list (ie from predefined message formats). Therefore suitable interfaces need to be provided for the AOC operator and the aircrew to compose these messages. Also, particularly on the aircraft, suitable notification of a new message is required for any messages that require a response.

3.5.6.5. Operating Method Without Operation Application

Currently, any decisions to change flight trajectory in-flight are handled on an ad-hoc basis. The request for change depends upon one of the involved parties (AOC or pilot) realising that a beneficial change is possible; by and large, the data to reach that conclusion is not readily available. The change is negotiated exclusively between the pilot and the current controlling ATCO; if the change affects downstream sectors, that involves the ATCO co-ordinating with the affected sectors before approving the change. There is no mechanism for AOC to negotiate directly with ATC. The function is possible, but there is no organised means of achieving it.

3.5.6.6. Operating Method With Operation Application

The ultimate CDM in-flight traffic management application is based on the exchange between ATC, AOC and aircraft of detailed planning information based on trajectories. The initial dialogue between AOC and pilot identifies the benefit of a change (based on an understanding of flight progress, airspace availability, forecast weather, etc.) Subsequently the change is negotiated with ATC, either by the pilot or by AOC. The new cleared trajectory is then distributed so both aircraft and AOC operate on the same data.

3.5.6.7. Application Time Constraints

This application is effectively part of a planning process, rather than tactical control, and is therefore rated as not time-critical. However, there is a requirement for the negotiation process to be completed in a timely fashion, and this may place constraints on the required communications performance to support the application.

3.5.6.8. Information Exchanges

The dialogue between AOC and aircraft is proprietary, and therefore the format of the data can be tailored to each individual AOC needs. However, the subsequent dialogues between AOC/aircraft and ATC will be standardised (standards not yet defined); there may therefore be a case for using a compatible format for the dialogue between AOC and aircraft.

3.5.6.9. Exception Handling

No exception handling will be required for AOC datalink communication. The failure of the AOC datalink will not affect the safety of the flight, but could affect the efficiency of the AOC fleet management.

4 Services

4.1 Communication Services

This section describes briefly the ATN communication services (ASEs and GACS) that could be implemented in a CMU (Communications Management Unit) to support the Operational Services as defined in the section 4.2.
The ASEs are fully described in the ICAO SARPs sub-volume 3 and GACS in the ICAO Doc 9705 Edition 3, sub volume IV.

In addition to these ATN services, a message broadcast service is also provided using the VDL Mode 4 data link technology.

4.1.1 ATN Services

4.1.1.1. Context Management (CM)

Context Management (CM) allows the aircraft to transmit its addresses/capabilities to ground peers and receive the peers ground systems addresses/capabilities.

For example if you meet a new person you would want to first find out information about an individual before you started a conversation (name background, where they are from, etc). Sometimes introductions are done by a third party. CM is this third party that introduces the airborne applications (i.e. CPDLC, ADS...) to the ground applications. The airborne CM application provides the following to the ground: airborne ATC applications available, addresses of the airborne ATC applications, and enough flight plan information to match the aircraft to a flight plan.

4.1.1.2. Automatic Dependent Surveillance (ADS)

ADS is defined by ICAO (Circular 256-ANI/152) as "a surveillance technique in which aircraft automatically provide, via a data link (e.g. satellite or VHF), data derived from on-board navigation and position-fixing systems, including aircraft identification, four dimensional position, and additional data as appropriate".
Although the ICAO definition refers explicitly to aircraft, ADS may also be used by ground vehicles. Together, aircraft and ground vehicles may be referred to collectively as "mobile platforms".
Using ADS, a mobile platform will send information in a surveillance message (an ADS report) to other systems via the data link.
The transmission of ADS data will be based on a contract between a ground system and an aircraft and then ADS is also known as ADS-C (ADS-Contract).

The following ADS contracts are defined and issued at the request of the ground system:
- Demand contract, in which an aircraft provides data immediately and once only.
- Periodic contract, in which an aircraft provides data periodically.
- Event contract, in which an aircraft provides information when certain events are detected by aircraft avionics.

The following ADS contract is defined and issued at the request of the airborne system:
- Emergency contract, in which an aircraft provides data on a regular basis with no prior agreement with the ground system, in the case of an emergency.

Surveillance data that can be provided using ADS include the following.

- Basic ADS (e.g. aircraft position, time and Figure Of Merit);
- Optional ADS information (e.g. ground vector, air vector, projected profile, meteorological
- information, short term intent, extended projected profile and aircraft identification)

4.1.1.3. Controller Pilot Data Link Communication (CPDLC)

The CPDLC system provides the capability to establish, manage, and terminate a communication connection between an aircraft and a ground system air traffic control authority via the ATN. Once an appropriate connection is established the CPDLC system provides for a pilot to exchange messages with the eligible air traffic controller.

When a message is received the CPDLC system decodes the data and determines the message urgency requirements, alerting requirements, and response requirements. These requirements then direct the CPDLC system concerning message display queuing, visual and aural alerting coding, and response availability. CPDLC also provides the capability to compose a message and encode the message for transmission.

4.1.1.4. Flight Information Services (FIS)

FIS is a mean of providing advice and flight information (e.g. ATIS and meteorological information) to aircrew using air/ground data communications for the safe and efficient conduct of flights.

The FIS application allows a pilot to request and receive FIS services from ground FIS systems. The FIS application is designed to enable FIS services to be provided to a pilot via the exchange of messages between aircraft avionics and ground FIS systems.

Two types of FIS contract may be established on request of the pilot: the *FIS Demand Contract* where the ground FIS system provides the information immediately and once only, and the *FIS Update Contract* where the ground FIS system provides the information every time it has been modified.

Multiple "FIS services" may be supported by the FIS application, as for instance: Automatic Terminal Information Services (ATIS), Precipitation Map Service, Terminal Weather Service (TWS), Windshear Advisory Service, Pilot Report (PIREP) Service, Notice to Airmen (NOTAM) service, and Runway Visual Range (RVR) Service.

4.1.1.5. Generic ATN Communication Service (GACS)

The Generic ATN Communication Service (GACS) allows a user of this service to transfer data transparently across the ATN to another user (or to multiple users).

The GACS can be used as an Application Entity (AE) of the ATN layer 7 stack and then avoids to implement an ATN "ASE" for each new use to which the ATN may be put. The ICAO Doc 9705 Edition 3 (sub-volume IV) permits GACS to be implemented also as an ASE and then to be part of another application.

The GACS provides an ATN access point to existing (e.g. ACARS-based) and future applications which are not specified as ASEs within the defined ATN upper layer architecture. This approach is appropriate for the migration of existing applications to the ATN by allowing current applications to exchange information using GACS as a standardized "enveloping" communications environment.

4.1.2 Broadcast services

4.1.2.1. ADS- Broadcast (ADS-B)

ADS-B is a service on an aircraft or a surface vehicle operating within the surface movement area that periodically broadcasts its state vector (horizontal and vertical position, horizontal and vertical velocity) and other information. ADS-B is automatic because no external stimulus is required to elicit a transmission; it is dependent because it relies on on-board navigation sources and on-board broadcast transmission systems to provide surveillance information to other users. The aircraft or vehicle originating the broadcast may or may not have knowledge of which users are receiving the broadcast; any user, either aircraft or ground-based, within the range of this broadcast, may choose to receive and process ADS-B surveillance information.

4.1.2.2. FIS-B (Flight Information Service - Broadcast)

FIS-B refers to the uplink transmission of certain data to support pilots in various phases of flight and includes messages such as ATIS, NOTAM, VOLMET, SIGMET, OPMET and meteorological data.

Most of FIS-B messages are automatically transmitted at a low update rate, typically every five minutes, These messages can be stored in the aircraft and selected for display by the pilot when needed. A new message will erase earlier messages to ensure that the most recent message is displayed. In some cases a previous message can be retained to allow the pilot to determine a trend in, for instance, Data link runway visual range (D-RVR).

4.1.2.3. **TIS-B (Traffic Information Service - Broadcast)**

TIS-B is a service that uses the capability of VDL Mode 4 to upload radar surveillance data from ground to aircraft. TIS-B will provide airborne situational awareness (AIRSAW) of nearby aircraft that are not ADS-B equipped to aircraft that are equipped with ADS-B and a cockpit display. This allows ADS-B equipped aircraft to have visibility of all aircraft traffic in the vicinity (both ADS-B equipped aircraft and non ADS-B equipped aircraft).

A ground station may up-link TIS-B messages with information about non ADS-B equipped aircraft. There are two types of message:

- TIS-B track message, which gives position information on up to four aircraft.
- TIS-B track identity message, which gives the flight identity (call sign) address of up to four aircraft.

The TIS-B tracks with call sign are intended to be displayed in CDTI (Cockpit Display of Traffic Information) data on a cockpit display.

The TIS-B track identity may be sent at a lower rate than the TIS-B track messages since they contain only static data. The reporting rate is an implementation option, but typical rates may be one report every 10 seconds per track for TIS-B track messages and once per minute per track for TIS-B track identity messages.
TIS-B messages may also be used by a ground station to re-transmit ADS-B reports. This can be useful when an aircraft transits into an area where a different channel is being used for ADS-B reporting. In this case, the ground station can provide aircraft in the new area with position information about the aircraft entering the area (and vice versa), long before the aircraft switches to the new channel.

TIS-B is an important application to deliver benefits from ADS-B in a partially equipped environment and therefore essential for providing supplementary surveillance information during the transition period.

4.1.3 Non ATN point to point support

This section covers the need for an airborne application to communicate to a ground station using the VDL Mode 4 data link without establishing an ATN connection. In this case the CMU will play the role of a simple bridge connecting an ARINC429 airborne network to a RS422 network (VDL Mode4).

4.2 Operational services

As stated in section 2.3, in year 2007, the ATSUs supporting the ODIAC operational services will equip the ACC and APPs, later the TWR will be equipped.

The objective of this section is to identify the need of operational services for each of the MA-AFAS application.
This section gives first the description of the communication services from the ODIAC ORD. Then for each of the MA-AFAS applications described in section 3 of this document, the required operational services are identified.

4.2.1 ODIAC data link Services Overview:

The ODIAC communication services are grouped by areas of similar functionality: Initialisation, Controller/Pilot Data link Communication (CPDLC), Automatic delivery of ATC Clearances, Automatic Down link of Airborne Parameters ADAP and Data Link Flight Information (D-FIS) services. Among the total list of ODIAC communication services some are still under definition. MA-AFAS will only use operational services that are already well defined. The description of these services are given in the following:

4.2.1.1. Initialisation service

Initiation Service (DLL)
This service encompasses all data link exchanges required to enable the other services. It represents in fact the initial access to the whole of the data link services system. Only aircrew are involved.

4.2.1.2. Controller/ Pilot Data Link Communications (CPDLC) Services

These services provide a means of communication between controller and aircrew, using data link for ATC communications, as a complement of voice communication. The following CPDLC services have been defined:

ATC Clearances (ACL)
This service involves both aircrew and controllers and deals with aircraft/ C-ATSU message exchanges and procedures for operations within the European region for all flight phases, including ground movements, for the following:

- Aircrew's reports and clearance requests;
- Controller's delivery of clearances, instructions and notifications to aircraft;
- Support and system messages.

The service description states also the rules for the combination of voice and data link communications and requirements and procedures for abnormal cases.

Downstream Clearances (DSC)
Aircrew, in specific instances, need to obtain clearances or information from ATSUs which may be responsible for control of the aircraft in the future, but are not yet in control of it. The DSC Service provides assistance for requesting and obtaining downstream ATSU clearances or information, using air/ ground data link and involving both aircrew and controllers.

Departure Clearance (DCL)
A flight due to depart from an airfield must first obtain departure information and clearance from the Controlling Air Traffic Services Unit (C-ATSU). The DCL Service provides automated assistance for requesting and delivering departure information and clearance, with the objective of reducing aircrew and controller workload and diminishing clearance delivery delays.

ATC Communications Management (ACM)
When a flight is about to be transferred from one sector or Air Traffic Services Unit (ATSU) to another sector or ATSU, aircrew are instructed to change to the voice channel of the next sector or ATSU to take control of the flight.
The ACM Service provides automated assistance to aircrew and current and next controllers for conducting the transfer of ATC communications. The ACM Service encompasses the transfer of all

controller/ aircrew communications, including the voice channel and the (new) data communications channel used to accomplish the ACM Service.

Dynamic Route Availability (DYNAV)
This service provides automated assistance for the proposal of alternative routes to aircrew as they become available (e.g. when military areas become free to civil use). This service is suited to take place automatically after FLIPCY (coming hereafter).

4.2.1.3. Automatic Downlink of Airborne Parameters ADAP services

The ADAP Services provide a means of supplying aircraft information and aircrew preferences to controllers and ground systems using air/ ground data communications. The ADAS services are :
Flight Plan Consistency (FLIPCY)
This service permits the ground system to check that flight data in the FDPS correspond to actual flight plan data from the aircraft. It should take place automatically at logon and involves controllers only.
Pilot Preferences Downlink (PPD)
This service permits the downlink of pilot preferences to the ground system for display to controllers. These preferences relate to flight parameters having operational implications for ATC and not requiring controller response.
Controller Access Parameters (CAP)
This service aims at enhancing the ATC surveillance and the availability of aircraft parameters to the controller by automatically extracting and downlinking data from the airborne system. Only the controllers are involved.

4.2.1.4. Data Link Flight Information (D-FIS) services

These services provide flight information (e.g; ATIS and meteorological information) to aircrew, in an automated mode and using air/ground data communications. D-FIS Services are the following:
Data Link Operational Terminal Information Service (D-OTIS)
The D-OTIS service provides automated assistance in requesting and delivering compiled meteorological and operational flight information derived from ATIS, METAR and NOTAMs/ SNOWTAMs, specifically relevant to the departure, approach and landing flight phases. Only aircrew are involved.
Data Link Runway Visual Range (D-RVR)
The D-RVR service provides automated assistance in requesting and delivering the Instantaneous Runway Visual Range (RVR) to aircrew.

4.2.2 Required Operational Services for MA-AFAS applications:

4.2.2.1. No Data Link

Within the MA-AFAS applications some can be conducted without any data link need like: 4D Navigation, Ground CDTI operation, Taxi Map Display, Runway Incursion Warning, Enhanced Situation Awareness, Autonomous Operation, Precision approach.

4.2.2.2. New Simple Clearances

Others like In-descent Spacing, Level Flight Spacing, Crossing, In trail require some new specific sets of clearances. They could be supported by the ATC Clearance Service (ACL) but require the implementation of new messages or the use of the existing free text message. The descriptions of these specific sets of messages are described in detail in the MA-AFAS procedures description document.

The typing of free text messages is adding workload to both controllers and pilots in addition human errors will be possible. It will also increase the pilot’s head down time which was shown as being very unsafe especially in approach phases.

For the previous reasons the In-descent Spacing application should be using point to point Data link only if dedicated messages are to be implemented. For the other applications, the criticality of head down time is not so strong and the use of free text messages could therefore be acceptable.

4.2.2.3. Complex New Services

The 4D negotiation is requiring complex and multiple exchanges. In the ODIAC services it should be defined within the COTRAC service which definition is still under refinement. This complex service can be decomposed on already existing simple services.
The 4D negotiation will used:

- DYNAV which could provide a good reason for 4D modification,
- DSC in case the negotiation needs information from a down stream centre,
- ACL to exchange the negotiated data, (In particular for the case of using this application in the FFAS environment specific messages referring to entry and exit of FFAS are needed.)
- FLIPCY to synchronise the flight plans at the beginning and at the end of the negotiation
- CAP will help the controller to refine its proposal
- PPD can be used for the pilot to initiate the negotiation in case the modification of flight plan is simple
- D-OTIS service can be used on board to refine the aircrew proposal or help understand the proposed controller flight plan.

MA-AFAS application	New ACL Message
4D Navigation	TBD

4.2.3 ADS-B/TIS-B for MA-AFAS applications:

In addition to the ODIAC services, ADS-B and TIS-B communication means are required for conducting the ASAS/CDTI and TAXI management MA-AFAS applications : ADS-B MASPS (RTCA/DO-242) provides standards that specify operational characteristics for ADS-B.
ADS-B is a function on an aircraft or a surface vehicle within the surface movement area that periodically broadcasts its state vector (horizontal and vertical position, horizontal and vertical velocity) and other information.
During the transition phase where not all aircraft will be ADS-B equipped, TIS-B can be a means of relaying the non ADS-B equipped aircraft data. To be considered TIS-B should allow to provide the minimum set of ADS-B data with the same performance requirements as ADS-B.

4.2.3.1. Minimum set of ADS-B data for MA-AFAS applications

The basic information to be conveyed by ADS-B shall include the following elements :

1. Call Sign : call sign or mode A code.
2. Aircraft Address : this code is used to uniquely identify the aircraft. It would be the aircraft 24-bit ICAO address if available.
3. Emitter Category
4. Lat, Long
5. Altitude
6. Time
7. Ground Speed
8. Track Angle

Call Sign

ADS-B shall convey an aircraft call sign of up to 7 alphanumeric characters in length [7]. For aircraft/vehicles not receiving ATS services and military aircraft the call sign is not required.

Address

The ADS-B system design shall) include a means (e.g., an address) to 1, correlate all ADS-B messages transmitted from the A/V and 2, differentiate it from other A/Vs in the operational domain.

Those aircraft requesting ATC services will be required in some jurisdictions to use the same 24 bit address for all CNS systems. Aircraft with Mode-S transponders using an ICAO 24 bit address shall use the same 24 bit address for ADS-B (meanwhile mode S is not in the scope of MA-AFAS). All aircraft/vehicle addresses shall be unique within the operational domain(s) applicable.

> Note 1. For example, all surface vehicles for a given airport need to have unique addresses only within range of the airport; vehicle addresses may be reused at other airports.
> Note 2. Correlation of ADS-B messages with transponder codes will facilitate the integration of radar and ADS-B information on the same A/V during transition.

Emitter category

The ADS-B emitter category shall refer to the characteristics of the aircraft or vehicle.

Longitude and Latitude

The horizontal latitude and longitude positions shall be reported as a geometric position.

Altitude

Both barometric and geometric altitude shall be reported, if available.

Time

The reports which will be provided by the ADS system shall include the time of applicability (validity) of the position measurement.
The time shall be expressed in hours/minutes/seconds.

Ground Speed

The ADS report shall include aircraft/vehicle derived ground speed.
The range of the ground speed shall be up to a max. of 4000 knots

Track Angle

The ADS system shall be capable of reporting the aircraft derived track angle.

4.2.3.2. TIS-B messages

TIS-B messages contain all information for each aircraft target as shown in next table.

Data	Comment
Target Identifier	A code to uniquely identify the TIS-B target. It will be the aircfart address (24 bit ICAO address) if available
ADS-B fused data flag	Indicates if the target has been fused with ADS-B information before transmission or otherwise if it is independent of ADS-B data.
ADS-B fault flag	Indicates if the corresponding ADS-B information diverts from the TIS-B information.
Latitude	Latitude
Longitude	Longitude
Barometric Altitude	At a resolution matched to 100ft or 25 ft increments (absolute value).
100ft or 25 ft altitude flag	Indicates accuracy of altitude.

Ground Speed (knots)	
Ground Track (degrees)	
Relative Time Stamp	Time stamp relative to a reference time every 1/5 minutes UTC synchronised; resolution 200 ms.
Flight Identity	Callsign or Mode A code
Aircraft Category	Category of aircraft or vehicle

5 Operational Scenario

This part, dedicated to operational scenario descriptions, illustrates interconnection between the different MA-AFAS application used during a "gate to gate" flight. These scenarios, are taking into account avionics and ground capabilities expected to be operational in the 2007 and 2015 timeframe. In all these scenarios the aircraft1 conducts the application

5.1 2007 Operational Scenario FRANKFURT – ROMA flight

This scenario particularly shows the use of data link medium available in 2007 during flight operation allowing information exchanges automation. It is expected that basic data-link services are available in this timeframe as specified in the Link2000+ implementation plan.

5.1.1 Pre-Flight phase

Before the flight, AOC will negotiate the flight plan. A Cooperative Decision Making process could enhance the negotiation.
6H.. : A commercial airline sends its proposed flight plans for its daily flight operations to Flow Management Institution and notably proposes a flight from Frankfurt to Roma Ciampino Airport. The departure and the estimated arrival time are respectively 9H40, and 10H54.
The flight plan negotiation between Airlines and Flow Management Institution is highly facilitated by Data-link use. Direct exchange of weather data, planned routings, and proposed altitudes is then possible.
7H..: Airlines selects a preferred company routing and altitude for own aircraft flight (cf. flight plan example, section 2.1)

5.1.2 From Gate to Push Back

5.1.2.1. Initialisation of systems

Aircrew1 initialises on-board systems :

1. Navigation sensors initialisation
2. SBAS/GBAS availability
3. Data-link medium initiation : the Datalink logon is performed with C-ATSU through DLL service
4. FMS initialisation
5. CDTI availability (it is assumed that aircraft1 is CDTI equipped)

5.1.2.2. Flight Plan and other relevant information up-link

9H...: Flight plan is transmitted by Data-link to Aircraft1 cockpit through gate-link and loaded in Aircraft1 FMS.

Aircrew1 requests D-ATIS service contract. Relevant information for flight operations are transmitted to cockpit. They concern :

- weather information,
- arrival and departure airport information.

Knowing these information, flight crew computes operational "pilot preferences" on on-board systems. Theses information related to flight parameters and constraints are down-linked through PPD service for display to controller and re-actualized automatically along the flight without any controller response necessity.

4D Trajectory Navigation Functions is activated. 4D trajectory is generated by the FMS taking into account flight plan and transmitted information (cf. 4D Trajectory Navigation, section 3.3.1). Aircrew1 activates the 4D trajectory.

5.1.2.3. The departure clearance

The departure clearance is requested by Aircrew1 through DCL service to ATSU-C, on reception the Controller performs a FLIPCY check of the FMS flight plan data, prepares departure clearance and delivers it by CPDLC.

5.1.2.4. Push Back

9H35 : Clearance for push is requested by Aircrew1. Clearance is delivered from ATC through CPDLC (ACL service).

5.1.3 From Push Back to Take off

5.1.3.1. taxi clearance

The MA-AFAS “Taxi management” functions are not yet implemented on own aircraft, so taxi maneuvers are conducted as today but using data-link medium

9H39 : Aircrew1 requests taxi clearance (cf. “Taxi clearance” function, section 3.2.3). Once obtained taxi clearance (ACL service), the requested taxi way is highlighted on the CDTI using specific symbology (cf. section 3.2.3). These information are added to ground traffic information already displayed. AOC application is activated (cf. section 3.5) enabling data communication between AOC and aircraft throughout the flight. Notably an automatic message from Aircraft1 to AOC is realized in order to indicate maintenance activity required if on-board system failure are detected all along the flight.

5.1.3.2. Taxi

Push back operations are now completed. Taxi begins to reach active runway for take-off, being n°(25L or 25R).

5.1.3.3. Take off

9H48 : Aircrew1 is now waiting at the active runway threshold. It completes take off briefing. Using ACL service, controller clears Aircraft1 to line-up on runway and soon after, to take off. The “Enhanced Situation Awareness application” is activated (cf. section 3.1.6). Surrounding traffic is displayed on Aircraft1 CDTI thanks to ADS-B and TIS-B messages.
4D Trajectory Navigation will operate all along the flight.
Take-off time is transmitted to upstream units using ground/ ground data communications. FLIPCY is initiated automatically by the ATSU.
9H49: Aircraft1 is now taking off.

5.1.3.4. From take off to cruise

During the climb out phase CIC dialogues take place, followed by ACM each time the flight enters a new sector or unit. FLIPCY checks are automatically performed and Conflict Detection and Arrival Manager tools make use of this information.

The controllers make use of the CAP Service to optimise sequencing and separation of flights. Also PPD information is used to check the preferred operating speed range of the aircraft.

5.1.3.5. Cruise

10H00 : Aircraft1 is flying Y163 route at FL 270, speed mach 0.8. The aircraft is following the active 4D trajectory (cf. Trajectory Navigation section 3.3.1).

CIC dialogues are performed. A DYNAV proposal is presented to aircrew, from an upstream unit. PPD information is displayed to the controller and in particular the actual requested flight level, as it may differ from the flight level requested in the filed flight plan. The cruise operating speed range is also available to the controller, enabling him to apply speed sequencing between two aircraft without having to request speed information from aircrews concerned. The controller also has available the CAP Service information, enabling his monitoring of compliance with tactical clearances.

10H31 : Controller has the opportunity to engage Level Flight Spacing (LFS) procedure (cf. “Level Flight Spacing” application, section 3.1.2) in order to prepare arrival in Roma airport. The target aircraft, Aircraft2, coming from Geneva and going to Roma Ciampino, is flying 20 NM ahead on the same track as Aircraft1. The controller requests (by voice and/or CPDLC message), Aircraft1 to be at MAREL point (Cf. flight plan example, section 2.1) at a time at which Aircraft1 will be 15 NM behind the target Aircraft2 for LFS activation. Aircrew1 estimates that he can follow the conditions proposed by controller, it means target aircraft, procedure starting point, separation in distance/time, clearance limit. Pilot accepts the LFS procedure (by voice and/or CPDLC message) and activates all LFS application sub-functions. Controller issues instruction through ACL service to Aircrew1 for LFS application activation. The trajectory is updated in Aircraft1 FMS in order to take into account the LFS conditions.
LFS application is started, the distance establishing and maintaining tasks are delegated to Aircrew1. Both aircraft are flying the same track, flying FL 310, mach 0.75, Aircraft1 remaining behind Aircraft2 at 15 NM.

Aircrew2 initiates a DSC dialogue with the arrival ATCU in order to prepare approach through knowledge of holding instructions and STARs. FLIPCY requests continue to be effected by the C-ATSU and several D-ATSUs. Aircrew input the Top of Descent and the preferred landing runway via the PPD Service.

Later on in this phase Aircrew may be provided with a Required Time of Arrival (RTA) sent by the arrival manager and uplinked via the CIC or the DSC Services, depending on the aircraft position.
Nearing Top of Descent, aircrew also initiates a D-ATIS contract for the arrival airport.

10H40: descent

Aircraft2 begins its descent from GRO point (Cf. flight plan example, section 2.1), in order to join Roma TMA and land in Ciampino Airport. The instructions specified to follow GRO1A STAR (cf. definition, section 2.1).
Aircrew2 inputs new PPD to inform the controller of their preferred landing runway and minimum clean configuration speed range.
CIC dialogues are performed. The D-ATIS contract is still active and during the approach phase aircrew2 initiates the D-RVR contract request. On the ground, the Runway Incursion warning tool is activated automatically.

5.1.4 From descent to landing

After having received “Top of Descent” clearance Aircraft1 begins descent.

The LFS procedure switches automatically in IDS procedure since the delegated aircraft (Aircraft1) has been cleared for TOD. Controller gives new instructions to Aircraft1, in order to reduce separation to 10 NM (or define a new separation in time meaning, on his convenience depending on his strategy and his constraints)

10H41 : Aircraft2 enters the TMA airspace, its speed is reduced to mach 0.62. The first aircraft of the pair is transferred to TMA controller. (each aircraft is transferred individually, using ACM service).

10H45 : Controller gives Aircraft2 new altitude instructions to issue a descent to FL 90. IDS and/or LFS application are still going on.

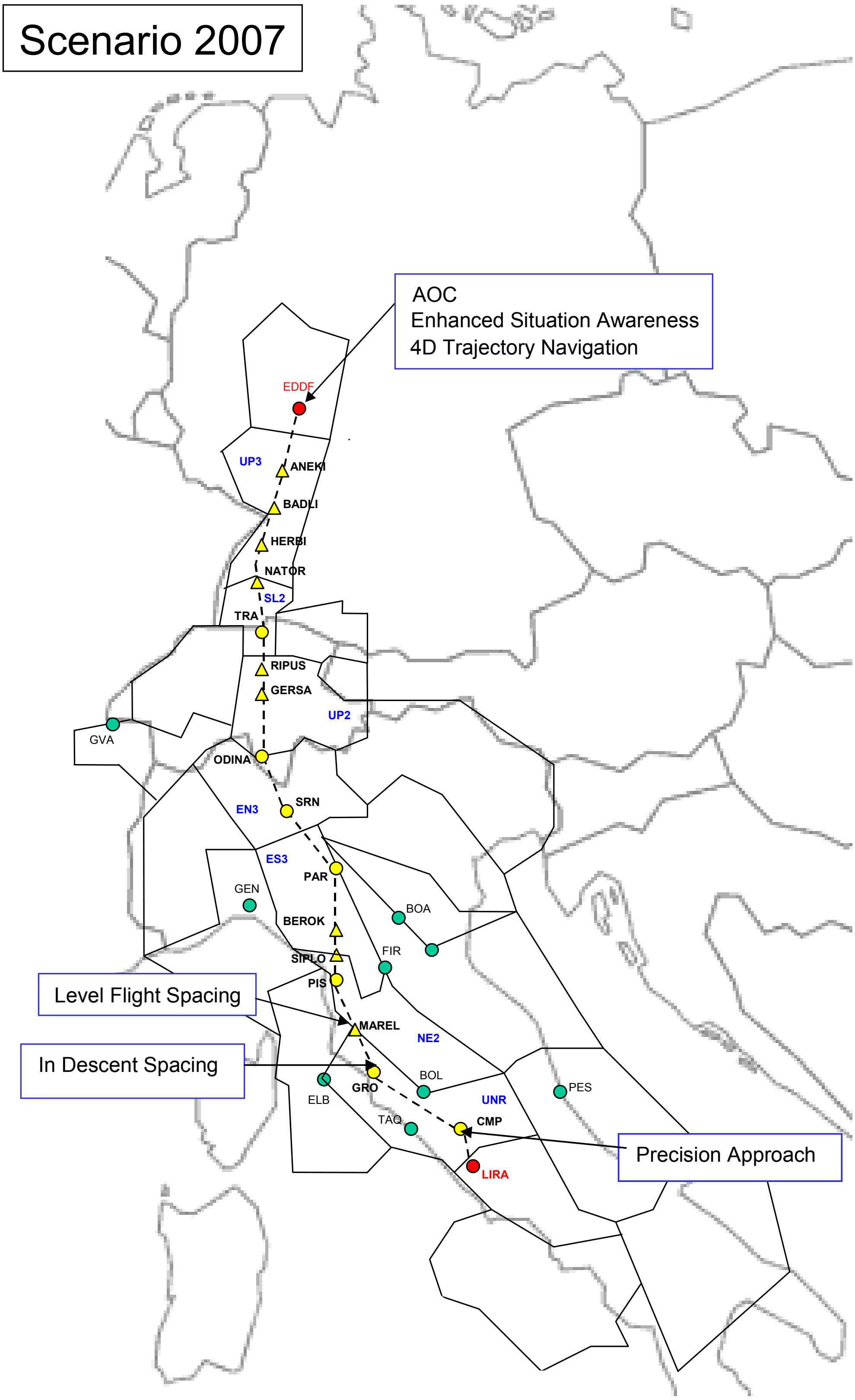
10H49 : Aircraft2 passes the CMP point, TMA controller informs (voice, D-link) Aircraft1 that IDS procedure is stopped (voice and/or CPDLC message). Aircraft2 activates “Precision Approach” application equipment (cf. section 3.4) and lands on Ciampino Runway n° (15 or 33).

10H51 : Aircraft1 passes CMP point, pilot activates “Precision approach” functions and starts final approach phase

5.1.5 From landing to terminal building gate

10H52 : Aircraft1 has landed on Ciampino airport on RWY 15 or 33. Taxi clearance is issued through ACL service after touch-down confirming that situation is conflict free. Taxi way operations are begun.

5.1.6 Considered Scenario representation



5.2 2015 Operational Scenario FRANKFURT – ROMA flight

This scenario constitutes an operational vision as a goal to evolve in the time frame 2015. Acquisitions from the previous scenario (2007 time frame) are assumed to remain stable. Flexible use of airspace for airspace users is notably illustrated with autonomous operations description taking place in FFAS during this gate to gate flight scenario.

5.2.1 Before the flight

Before the flight, AOC will negotiate the 4D trajectory. A Cooperative Decision Making process could enhance the negotiation.
6H..: A commercial airline sends its proposed flight plans for its daily flight operations to Flow Management Institution and notably proposes a flight from Frankfurt to Roma Ciampino Airport. The departure and the estimated arrival time are respectively 9H40, and 10H54.
The flight plan negotiation between Airlines and Flow Management Institution is highly facilitated by Data link use. Direct exchange of weather data, planned routings, and proposed altitudes is then possible.
7H.. : Airline selects a preferred company routing and altitude for Aircraft1 flight.

5.2.2 From Terminal Building Gate to Push Back

5.2.2.1. Initialisation of systems

Aircrew1 initialises on-board systems :

6. Navigation sensors initialisation
7. GBAS/GRAS availability
8. TIS-B/ADS-B receiver/transmitter availability
1. Data-link medium initiation : the Data-link logon is performed with C-ATSU through DLL service
2. FMS initialisation
3. CDTI availability

5.2.2.2. “Ground CDTI” activation:

9H.. : “Ground CDTI” and “Map display” applications are activated for situation awareness. Ground vehicles positions and short term intentions, airport infrastructures (building, taxi ways…) in the vicinity of Aircraft1 are displayed on pilot CDTI. (Cf. Taxi Management application, section 3.2)

5.2.2.3. Flight Plan and other relevant information up-link

9H.. : Flight plan is transmitted by Data-link to Aircraft1 cockpit through gate-link and loaded in Aircraft1 FMS.

Other relevant information are loaded in cockpit through Data link (D-OTIS service):

- weather information.
- information concerning arrival and departure airport.

4D Trajectory Navigation Functions is activated. 4D trajectory is generated by the FMS taking into account flight plan and transmitted information (cf. 4D Trajectory Navigation, section 3.3.1). Aircrew1 activates the 4D trajectory.

5.2.2.4. The departure clearance

The departure clearance is requested by aircrew through DCL service to ATSU-C. On reception the controller performs a FLIPCY check of the FMS flight plan data, prepares departure clearance and deliver it by D-link.

5.2.2.5. Push back

9H35 : Clearance for push is requested by Aircrew1. Clearance is delivered from ATC through CPDLC (ACL service).

5.2.3 From Push Back to Take off

5.2.3.1. Taxi clearance

9H39 : The aircrew1 requests taxi clearance (cf. "Taxi clearance" function, section 3.2.3). Once obtained taxi clearance (ACL service), the requested taxi way is highlighted on the CDTI using specific symbology (cf. section 3.2.3). These information are added to ground traffic information already displayed. AOC application is activated (cf. section 3.5) enabling data communication between AOC and aircraft throughout the flight. Notably an automatic message from Aircraft1 to AOC is realized in order to indicate maintenance activity required if on-board system failure are detected.

5.2.3.2. Taxi

Push back operations are completed. "Runway alert" function is now active (cf. section 3.2.4).

Taxi begins to reach active runway for departure, being n°(25L or 25R). External weather conditions are bad. Consequently because of poor visibility, Aircrew1 is about to enter unintentionally on the chosen runway before controller has given clearance. The runway alert warning is raised (as described in section 3.2.4). Maneuver is held by Aircrew1 in order to avoid incursion.

5.2.3.3. Take off

9H48 : Aircrew1 is now waiting at the active runway threshold and completing take off briefing. Using ACL service, controller clears Aircraft1 to line-up on runway and soon after, to take off. "Enhanced Situation Awareness" application is activated by aircrew (cf. section 3.1.6). 4D Trajectory Navigation will operate all along the flight.

9H49 : Aircraft1 is now taking off.

5.2.4 From take off to cruise

9H52 : The Aircraft1 is climbing faster than aircraft2. ATC requests Aircrew1 to accomplish a vertical crossing (voice and/or CPDLC). Once Aircrew1 has finished the crossing, the climb phase is continued.

5.2.5 Cruise phase

9H57 : Aircraft3 is flying the same track in front of Aircraft1 but at a much lower speed. Aicraft1 is requested by ATC (voice and/or CPDLC) to perform a lateral passing.
10H00 : Aircraft1 is now flying Y163 route at FL 270, speed mach 0.8. The aircraft is following the active 4D trajectory (cf. **Error! Reference source not found.** section **Error! Reference source not found.**)

5.2.6 From MAS to FFAS

FFAS boundaries (cf. environment definition, section 2) appear on pilot CDTI.

10H02 : 5 minutes before crossing boundary, the controller checks complexity/density in the MAS-FFAS transition zone, and gives his last instructions to Aircrew1 (voice and/or CPDLC message). He specifies a heading to be followed until border is crossed, and clears Aircrew1 to enter in FFAS (by voice and/or ACL service).

The onboard system computes a new 4D trajectory: Aircraft1 will fly the requested heading up to the FFAS intersection, then a direct route up to the exit point and finally the remain part of the trajectory to the gate including the already defined exit point.

Aircrew1 accepts clearance and the full responsibility of separation assurance, starting at the entry into FFAS. The pilot activates all autonomous operation sub-functions (CD&R functions) however the controller is still monitoring the Aircraft1 until entry is effective. The manoeuvre to meet the new specified heading is started.
A conflict is detected between Aircraft1, still climbing, and aircraft 4 in cruise within the FFAS. An aural and a visual alarm are displayed. The onboard system modifies the trajectory inside the FFAS respecting the FFAS borders and the exit way point conditions.

The conflict is computed to take place 6 minutes after entering the FFAS. Both aircraft will be in cruise phase in FFAS. Aircraft4 is the closest in distance to the point of loss of separation, by applying EFR rules, it has the right of way. A conflict free default trajectory is displayed on the Aircrew1 CDTI (the trajectory can be modified only on the portion of the flight plan that is within the FFAS in accordance with exit conditions contained in flight plan if possible).This trajectory is consistent with airline needs, and the necessity to also avoid external bad weather conditions zone which are in the useful range of on-board weather radar.

5.2.7 In FFAS

10H07 : Entry into FFAS:

Aircraft1 enters in FFAS at the previously defined entry point. When Aircraft1 enters in FFAS, the conflict resolution solution is activated. The maneuver corresponding to an accepted solution is automatically performed thanks to an interface between FMS to auto pilot. The new Aircrew1 intents are broadcasted while 4D navigation is still active on the trajectory.

10H09 : A new conflict, between Aircraft1 and Aircraft5, is detected. Aircraft5 is coming from east and flies its preferred route to Geneva in FFAS. The conflict zone is located at 20 NM on the east of ODINA point (cf. flight plan example, section 2.1), the time before encounter is 10 minutes ahead.
Both aircraft are in the same flight phase, in cruising phase. Aircraft5 is the closest in distance to the point of loss of separation, by applying EFR rules, it has the right of way. Aircrew1 identifies on its CDTI that it has to maneuver. Using the conflict resolution module of its ASAS equipment, a conflict free default trajectory is displayed on Aircrew1's CDTI for validation.

The pilot doesn't react in time and the time to the conflict is now 5 minutes. The tactical algorithm is used which means that both aircraft are assigned to maneuver co-operatively. When the maneuver is ended a new trajectory is generated still as a direct conflict free route to the exit point.

10H13 : Maneuver is accomplished, all conflict alarms are cleared. Both pilot continue to monitor situation evolution.

10H21 : Aircrew1 is alerted thanks to on board weather radar report that a thunderstorms area is developing at S.W of Parma. This bad weather area is displayed on the pilot CDTI.

An avoidance solution is provided by the conflict resolution system. This solution implies both heading change and climbing to FL 310 maneuvers. This maneuver is consistent with a low cost re-routing.

10H22 : The avoiding solution is validated by pilot, the new direct route is updated in the Aircraft1 FMS.
10H23: Maneuver is automatically or manually accomplished.

5.2.8 From FFAS to MAS

10H31 : 10 minutes before exiting FFAS,

FFAS-MAS transition controller has checked that situation is conflict free. He has the opportunity to engage a Level Flight Spacing (LFS) procedure in order to prepare arrival in Roma airport. The target aircraft, Aircraft6, coming from Geneva and going to Roma, is flying 20 NM ahead in FFAS. Aircraft6 has already negotiated with the transition controller its exit conditions and is cleared to exit FFAS at the MAREL point. The controller requests Aircrew1 to exit FFAS at MAREL (Cf. flight plan example, section 2.1) at a time at which Aircraft1 will be 15 NM behind the target aircraft6. Aicrew1 confirms that he can meet the constraint at MAREL point. The 4D trajectory is updated in order to take into account these new exit conditions (cf. "4D navigation application", section 3.3.1).

10H38 : LFS initiation

Aircraft6 has just returned in MAS airspace on UA41 route, ground controller proposes to Aircrew1 to establish LFS (cf. "Level Flight Spacing" application, section 3.1.2) with Aircraft6 in MAS, by voice and/or CPDLC. Pilot identifies the target as Aircraft6, and estimates that he can follow the condition proposed by controller (target aircraft, procedure starting point, separation in distance/time, clearance limit). Aircrew1 accepts the LFS procedure. Controller issues clearance (ACL service) to Aircrew1 for LFS application activation after the FFAS border is crossed at the predetermined point. Aircrew1 activates all LFS application sub-functions and adapts speed if necessary.

10H39: LFS activation
After Aircraft1 has returned in MAS, LFS application is started, the distance establishing and maintaining tasks are delegated to Aircrew1. Both aircraft are flying the same track, flying FL 310, mach 0.75, Aircraft1 remaining behind aircraft6 at 15 NM.
10H40: descent
Case a: Aircrew6 receives TOD instructions from ground controller (CPDLC message) and begins its descent from GRO point (Cf. flight plan example, section 2.1), in order to join Roma TMA airspace and land in Ciampino Airport. Previous instructions specified that to follow GRO1A STAR (cf. definition, section 2.1).
Case b: Before "Top of Descent", Aircrew6 generates a preferred arrival trajectory that is updated after a 4D trajectory negotiation with ATC via CPDLC (cf. section 3.3.1). The new preferred trajectory is cleared by ATC through ACL service.

5.2.9 From descent to landing

Aircraft1 now begins descent, after having received "Top of Descent" instructions.

The LFS procedure switches in IDS procedure since the delegated aircraft (Aircraft1) has been cleared for TOD. Controller gives new instructions to aircrew1, in order to reduce separation with Aircraft6 to 10 NM (or define a new separation in time meaning, on his convenience depending on his strategy and his constraints). Instructions are transmitted through ACL messages.

10H41: Aircraft6 enters the TMA airspace, its speed is reduced to mach 0.62. The first aircraft of the pair is transferred to TMA controller (each aircraft is transferred individually using ACM service).

10H45: Controller gives Aircraft6 new altitude instructions to issue a descent to FL 90. IDS and/or LFS application are still going on.

10H49: Aircraft6 passes the CMP point (Cf. flight plan example, section 2.1). TMA controller informs (voice and/or CPDLC message) aircraft1 that IDS procedure is stopped. Aircrew6 activates "Precision Approach" application equipment (cf. section 3.4) and lands on Runway n° (15 or 33).

10H51: Aircraft1 passes CMP point, pilot activates "Precision approach" functions and starts final approach phase.

5.2.10 From landing to terminal building gate

10H52 : Aircraft1 has landed on RWY 15 or 33. " Map display", "Ground CDTI " and "Runaway alert" applications are activated. Taxi clearance is issued by Data link (ACL service) after touch-down confirming that situation is conflict free. Taxi way operations are begun. Ground traffic situation is monitored by Aircrew1 until parking operations are completed.

5.2.11 Considered Scenario representation