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iFly

Safety, Complexity and Responsibility based design and
validation of highly automated Air Traffic Management

Specific Targeted Research Projects (STREP)

Thematic Priority 1.3.1.4.g Aeronautics and Space

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Autonomous Aircraft Advanced (A^3) ConOps

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Abstract

The iFly project definition comes as a response to the European Commission 6th Framework Programme call for Innovative Air Traffic Management (ATM) Research in the area of 'Aeronautics and Space'. The iFly research project is expected to develop novel concepts and technologies with a fresh perspective into a new air traffic management paradigm for all types of aircraft in support of a more efficient air transport system. It is aimed at supporting the integration of collaborative decision-making in a co-operative air and ground ATM end to end concept, validating a complete ATM and Airport environment, and takes into account the challenging objectives of Single European Sky (SES) and EUROCONTROL's ATM2000+ strategy.

The development of the iFly operational concept (ConOps) will consist of two design and one assessment cycles. The resulting concept, designed for a timeframe beyond SESAR (2025+), is aimed at managing a three to six times increase in current air traffic levels, while improving today's safety levels and system efficiency. The first design cycle will result in a concept called the Autonomous Aircraft Advanced (A^3) concept. This concept envisages a net-centric environment in which all aircraft are responsible for airborne self separation (SSEP), without ground support from Air Traffic Control (ATC), while meeting traffic flow constraints. The second concept cycle will take the results from the iFly analysis and validation phase to enhance the A^3 concept with ground support where needed.

The A^3 ConOps scope is limited to en-route flight only, which is defined from the Terminal Manoeuvring Area (TMA) exit point at the departing TMA to the TMA entry point at the arriving TMA. This en-route airspace is classified as Self Separating Airspace (SSA) where autonomous aircraft use Autonomous Flight Rules (AFR) to separate themselves from all other traffic and hazard areas Autonomous aircraft are free to fly the trajectory of their choosing, as long as they remain separated and meet predetermined traffic flow management constraints (i.e. Controlled Time of Arrival at arriving TMA).

The enablers for the A^3 ConOps include a System Wide Information Management (SWIM) network, air and ground datalink to broadcast and receive surveillance information from nearby aircraft and flight deck decision support tools, enabling the flight crew to operate in this new environment. Ground support functions will provide surveillance information on aircraft and hazard areas that are outside direct Air-Air Data Link range but which might be of interest to the flight.

Information from both air and ground (SWIM) will be used by the on-board system for Long Term Area avoidance, Medium and Short Term Conflict Detection & Resolution, Conflict Prevention and Collision Avoidance. The on-board system will also include functions to detect and avoid areas of high traffic complexity. Combined with a Trajectory Management unit the system will provide trajectories optimized for safety, efficiency and passenger comfort.

In addition to operational aspects, which include a description of the procedures, rules and responsibilities and enabling technologies, the document also provides some guidelines in support of Human Factors, Human Machine Interface (HMI) development and operational scenarios, which include examples for normal, non-normal and emergency operations. In

order to establish a regulatory background to the A^3 ConOps, the current and future developments in regulations have also been addressed.

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CHAPTER I Introduction and Background

1 Introduction

1.1 Contribution of this Report

This report aims to continue the development of an Autonomous Aircraft Advanced (A^3) ConOps as a conceptual description of a future airborne self separation operation in the en-route phase of flight. The flight crews of such aircraft will be able to ensure separation from neighbouring traffic and other obstacles, without the assistance of ground-based Air Traffic Control (ATC). This is enabled by advanced airborne systems with new surveillance and trajectory management capabilities. In addition to separation management these systems allow for effective trajectory optimization while meeting traffic flow constraints. Future advanced Air Traffic Management (ATM) research environments (SESAR and NextGen) and other on-going research projects, as well as human factors considerations and the current state-of-the-art in Airborne Separation Assistance System (ASAS) research, have been taken into account in deliverable D1.3.

Interactions with other iFly deliverables: previously released deliverables from WP1 (High level A^3 ConOps report D1.1 and Traffic flow study report D1.2) and WP2 (Human factors analysis reports D2.1 and D2.2) which present studies on the technological and human factors aspects involved in the operations of autonomous aircraft have been used as a starting point for the A^3 ConOps redaction. D1.3 is a key deliverable in the iFly project, as it provides the input for those Work Packages which will either focus on developing technologies whose requirements arise from the ConOps (WPs 3, 4 & 5), or will perform cost/benefit and risk/safety assessments of the ConOps itself (WPs 6 & 7). A^3 ConOps Safety brainstorming outcomes of the WP7.1 workshop were taken into account along present deliverable versions evolution. The conclusions of this brainstorming were collected in the minutes May 30st 2008. Finally the deliverable D10.1.i describes the way how iFly activities comply with the E-OCVM validation approach.

Interactions with other outside deliverables: WP1.3 takes advantage of results from other projects related and used as inputs in order to develop D1.3., for instance: previous AMFF concept [13], outcomes of initial safety risk evaluation of AMFF concept carried out by Hybridge project [24,25], NASA report on an advanced en route design [14], RESET proposed reduced separation minima for en-route [22], SESAR deliverables [18,19,20,21], among many others mentioned in Appendix VI - List of references.

1.2 iFly's Objectives

The iFly project proposal was a response to the European Commission's 6th Framework Programme call for Innovative Air Traffic Management (ATM) Research in the area of 'Aeronautics and Space'.

Air transport throughout the world, and particularly in Europe, is characterized by major capacity, efficiency and environmental challenges. With the predicted growth in air traffic, these challenges must be overcome to improve the performance of the ATM system. The iFly project addresses these critical issues by developing a paradigm step change in advanced ATM concept development through a systematic exploitation of state-of-the-art mathematical techniques including stochastic modelling, analysis, optimisation and Monte Carlo simulation.

The iFly project will develop and analyze a highly automated ATM concept for en-route traffic, which takes advantage of autonomous aircraft operation capabilities and which is intended to manage a ***three to six times increase over 2005 en-route traffic demand***.

The proposed iFly research combines expertise in air transport human factors, safety and economics with analytical and Monte Carlo simulation methodologies supporting the integration of collaborative decision-making, standardisation and regulatory frameworks.

Specifically, iFly will perform two operational concept design cycles and an assessment cycle comprising human factors, safety, efficiency, capacity and economic analyses. The general work structure is illustrated in Figure 1-1.

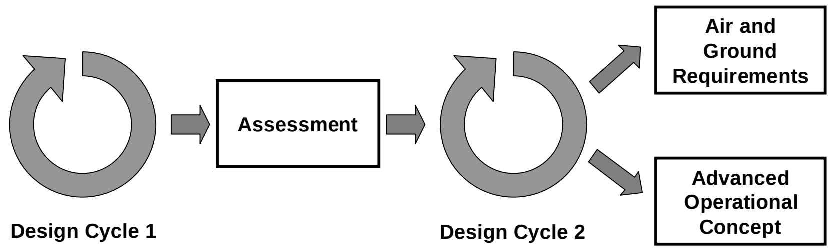

Figure 1-1 iFly Work Structure

During the first design cycle, state-of-the-art Research, Technology and Development (RTD) aeronautics results will be used to define a "baseline" operational concept. For the assessment cycle and second design cycle, innovative methods for the design of safety critical systems will be used to develop an operational concept intended to manage a three to six times increase in current air traffic levels. These innovative methods find their roots in robotics, financial mathematics and telecommunications, and have been identified by the RTD programme "HYBRIDGE" (EC 5th Framework Programme) as being utilized for advanced ATM design.

Autonomous aircraft operations, which include airborne self separation, present a potential solution to the capacity problems that will be encountered in en-route airspace in upcoming years, at the currently predicted rate of growth for air transport. The reason for this is that in general (except in terminal areas around airports) the human-centred separation assurance method, and not the airspace volume itself, is the most limiting factor on capacity, and that a shift from ground-based to airborne separation and trajectory management responsibilities is expected to result in a more capable, flexible and reliable en-route ATM system.

iFly will explore the airborne self separation alternative as a potential solution for high traffic density airspace, therefore the iFly key research question is: ***up to which en-route traffic demands is airborne self separation sufficiently safe?***

The iFly project brings together a skilled team from European ATM research and industry that initially came together in the completed EC-INFSO project HYBRIDGE. The consortium is strengthened by specialists in human factors, aviation psychology and cost-benefit analyses, together with a large Air Navigation Service Provider (ANSP) and a large system engineering consultant with wide experience in advanced ATM design.

1.3 iFly Work Package 1 (WP1)

Along with the Autonomous Aircraft Advanced operational concept (A^3), Work Package 1 also developed an airline strategy concept for autonomous aircraft operations, using state-of-the-art aeronautics research and technology results. The airline strategy concept for the A^3 environment, is intended to optimise airlines performance with autonomous aircraft and to improve customer services by making effective use of that autonomy.

WP1 has taken advantage of state-of-the-art research results obtained in previous aeronautics research projects and has leant significantly on the pilot responsibility and cognition analysis performed within Work Package 2 [8] and [9].

The tasks performed in WP1 have been consolidated around this A^3 ConOps, which is targeted to:

- Safely accommodate as much en-route traffic demand as it is feasible.

- Improve on meeting the airspace users' preferences by making effective use of autonomous navigation capabilities.

- Optimize the performance of airlines with autonomous aircraft.

WP1 is organized in three sub-WPs:

- WP1.1, "High level ConOps" described the research efforts and available options gathered towards autonomous en-route aircraft advanced operations (iFly - D1.1). The deliverable is a high level approach to the A3 concept of operations to be developed for a potencial shift into autonomous en-route operations in busy airspace according to current standards. This deliverables describes the high level operational procedures for en-route aircraft operations and defined the airborne trajectory separation management responsibilities and tasks within the Self Separation Airspace (SSA).The document presents the types of hazards that must be addressed within A3 ConOps to ensure that autonomous aircraft operations in medium to high density airspace can be realized at safety levels that are equal o superior to the safety levels of the existing ATM environment.

- WP1.2, "Airline Strategy Concept" described the strategy concept for airline operations in an autonomous aircraft environment (iFly – D1.2).This Deliverable provides an overview of possible airline strategies to make optimal use of operating in an A3. This is done by a three step approach. First of all, the current day airline problems are identified, through extensive literature study on airline operations. Secondly, an extensive list of candidate strategies are identified which can be used by airlines to improve their operations in an Advanced Autonomous Aircraft environment. In the third step, an airline operational concept is identified, which uses the candidate strategies as a starting point

- WP1.3, "ConOps" describes the overall concept of operations within the autonomous en-route ATM environment (iFly - D1.3). This deliverable presents a conceptual description of the futue operation of autonomous aircraft in the en-route of flight as well as the high level specification for the required equipment.

1.4 Deliverable D1.3 Scope

This document aims to provide a functional and versatile autonomous aircraft, non-ATC supported Operational Concept that lays down the foundation for the work in subsequent WPs, by providing information about several basic topics, which are required for the development of airborne self separation applications. A recollection of these topics is presented, alongside a very short, one-sentence condensation of the contents related to them provided by the A^3 ConOps, in order to provide a concise, first-glance impression:

- Specific new classes of airspace – *Self Separating Airspace (SSA), where no ATC separating services are provided.*

- Specific rules for airspace access – *Requirements for transition into or out of SSA are presented.*

- Standards for airborne separation minima – *Suitable airborne separation minima, taking into account projected increases in navigation performance and ongoing research[1], have been defined in section 8.3 - Aircraft Separation.*

- Specific autonomous flight rules – *A set of Autonomous Flight Rules (AFR), which serve as a framework for autonomous aircraft operations, are presented.*

- Roles, tasks and responsibilities for flight crews and controllers – *Tasks and responsibilities regarding flight crews are analysed and described.*

- Trajectory management and separation assistance functios – *A complete description of an airborne multi-layered trajectory management system that provides airborne collision avoidance, airborne separation assistance and longer-term trajectory management is provided.*

- Aircraft communications and surveillance capabilities – *Both Air-Air Data Link and SWIM communications are fused to provide adequate traffic situational awareness to flight crews; additional automated ground support functions are added to enable these capabilities without putting too much pressure on the technological requirements on the airborne side.*

- High-Level equipment and technology requirements in order to enable autonomous aircraft operations – *High level conceptual descriptions of recommended or desired equipment characteristics are provided, in terms of minimum performance requirements in order to comply with the operational assumptions presented in this ConOps.*

1 EC – RESET project (RST-WPX-AEN-033 - List of reduced separation standards for prioritization - Technical Report-V1.1).

1.5 Organisation of this report

This A^3 ConOps document is organised as follows:

Chapter I – Introduction and Background presents an overview of the current and foreseen ATM environment demands and the iFly project, WP1 and D1.3 structure and objectives:

- Section 1 offers a description of the structure and objectives of the iFly project, as well as the demands and requirements placed upon Work Package 1 work. It also summarizes the topics that are considered in the ConOps, gives a quick review of some of the statements that are presented, and showcases the overall structure of the document.

- Section 2 describes and explains both the current and future air traffic situation, in terms of the air traffic demands placed upon the current ATM system, the future demands to be expected and of the future changes that are foreseen to accommodate them.

Chapter II – Concept of Operations consists of the main body of contents presented in this document; the A^3 ConOps is properly described hereunder.

- Section 3 provides an airspace classification that introduces Self Separating Airspace (SSA), and explores the resulting airspace structure and boundaries.

- Section 4 lists the general assumptions made for the A^3 ConOps, which delimit the field of application of this operational concept and present the initial requirements needed for A^3 operations.

- Section 5 lists the enablers: those elements that are deemed necessary for the succesful development of the A^3 ConOps.

- Section 6 presents a basic flight description, from departure TMA to arrival TMA.

- Section 7 explains the pre-flight process of Strategic Flow Management, which aims at providing a strategically deconflicted airspace, prior to the actual flights taking place.

- Section 8, *Autonomous Flight Operations*, presents a description of aircraft operations under the A^3 ConOps which is divided in:
  - flight crew roles, tasks and responsibilities;
  - the conflict environment that aircraft encounter while in-flight;
  - definition of the aircraft Protected Airspace Zone (PAZ) in terms of airborne separation minima;
  - the defined set of Autonomous Flight Rules (AFR);
  - the conflict detection and resolution process;
  - the considered priority rules;
  - transition operations;
  - military operations, and;
  - non-normal and emergency operations.

- Section 9 provides a description of the A^3 systems, both the communications and surveillance system scheme and functionalities and the cockpit/airborne system architecture and functionalities. Human factors considerations about human/machine interactions, responsibilities and workload are also presented here.

Chapter III – Regulations and Conclusions presents additional material that will allow for a more complete immersion in the environment of the A^3 Concept of Operations.

- Section 10 deals with considerations on regulations, firstly on the current state of regulations regarding Airborne Separation Assistance Systems (ASAS) and then on the measures needed in the future to allow for the succesful implementation of an operational concept similar to the A^3 ConOps.

- Section 11 is a presentation of the most relevant aspects of the ConOps, as well as a self-assessment of the work done, pointing in a preliminary way at all those aspects to be improved in the iFly Design Cycle 2 iteration.

The ***Appendices*** consist of additional background material:

- Appendix I provides a set of operational scenarios, with the purpose of illustrating situations that may expose interesting features (and possibly weaknesses and bottlenecks) of the A^3 ConOps.

- Appendix II consists of a description of the relationships of the A^3 ConOps with ATM strategic research programs (SESAR in Europe and NextGen in the US).

- Appendix III presents a compilation of the state-of-the-art in ASAS and self separation research.

- Appendix IV provides a list of relevant ICAO regulatory texts.

- Finally, Appendix V presents an acronyms list, and Appendix VI provides a list of references.

2 Background – Air Traffic demands

This section is based on the adapted text of major SESAR deliverables, in particular:

- D1, Air Transport Framework – The Current Situation, considering the description of the current ATM system[2].
- D3, The ATM Target Concept[3], and D4, The ATM Deployment Sequence[4], considering the future ATM System.

Further details about the relationship between A^3 and the SESAR and NextGen strategic programs are provided in Appendix I.

2.1 Current ATM System

From a business perspective, the current role of ATM is to deliver air navigation services (ANS) to airspace users primarily in the form of en-route and airport ATC services. This is done using procedures, people and engineering systems located mainly within en-route ATC centres and at airports. At these locations data processing systems are connected to ground based communications, navigation and surveillance (CNS) infrastructure systems which provide information support services that are functionally compatible with corresponding systems on-board the aircraft. The role of ATM is also to conduct, in conjunction with the airspace users, the airspace management process referred to as Airspace Organisation & Management (AOM), which also embraces the "organisation" of airspace as determined by the airspace providers on behalf of their sovereign governments. This must balance the needs of commercial airspace users with those of the Military, General Aviation and others. ATM also provides Air Traffic Flow Management (ATFM) (which operates to support a regime of demand / capacity balancing (DCB)) as well as meteorological and Aeronautical Information Services (AIS).

As stated above, the current provision of ANS is based on the concept of ATC being provided by ground ANS Provider (ANSP) services. The evolving ATM System of today has over time maintained this basic concept and introduced improvements to it to supply capacity whilst maintaining safe operation. However, in general, these improvements have been made in a piecemeal manner. In Europe there are numerous ATM/CNS legacy systems and operational procedures in service today, which have varying capabilities and various degrees of complexity. They are deployed to meet the growing demand for ANS, but without any overarching ATM concept or functional architectural design involving all ATM stakeholders, or the framework to create an efficient, performance based ATM System.

From the operational point of view, the present system capacity is highly dependent upon the role of the controllers, their ability and the level of technical system support provided to them. Current automation levels are limited in their functional capability to support the human operator to build a 4-D traffic picture; it is left to the controllers and their skills and training to

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[2] SESAR D1, DLM-0602-001, http://www.sesar-consortium.aero/deliv1.php
[3] SESAR D3, DLM-0612-001-02-00a, http://www.sesar-consortium.aero/deliv3.php
[4] SESAR D4, DLM-0706-001-02-00, http://www.sesar-consortium.aero/deliv4.php

reach the performance levels required. Without the appropriate supporting tools the human's ability to build 4-D traffic pictures is limited. Initial steps have been taken to improve coordination between controllers and the ATC ground systems and facilities. The operation is hindered by the limited availability of information and constraints in the sharing of information between the stakeholders, as well as the fragmentation of airspaces and the excessive required coordination between all participants.

SESAR D1 document concludes the analysis of the current ATM system with a set of conclusions and recommendations that include:

- ATM today is predominantly a tactical air traffic control process supported by a number of management planning functions.

- ATM service provision in Europe is considered to be expensive, especially when compared to the US. This is due to the fragmented nature of the way in which the terms of the 1944 Chicago Convention have been implemented on a State-by-State basis. This has led to the development of national infrastructures which have low levels of interoperability, limited sharing of data, little cooperative planning in the way their assets are managed, replaced and upgraded and many area control centres which are considered to be sub-optimal in size with respect to the levels of traffic they handle.

- Today's ATM process is based upon a “first come, first served” principle, so accommodating the needs and providing ANS to all airspace users. However, this is not adequately geared to maintaining the schedules of commercial airspace users.

- Access to and use of the radio spectrum is vital for the continued provision of safe ATM services, these being based upon the ability to derive and exchange high integrity information between the various infrastructure systems which underpin them.

- The adaptability of the current ATM System is limited. Many aspects, such as route structures, airspace sector structures, controller validations, procedures, the functionality of the ground systems, etc., have, in the past, been fixed by design. As a result there is an inherent mismatch between the long lead times it takes to bring new ATM capacity into operation and the shorter time it takes for airlines to open new routes and services. Therefore, in the main, demand has always exceeded capacity.

- At European level there is no clear architectural design or notion of an ATM System. The one which exists in operational service today is predominantly a plethora of legacy systems which have been designed, procured and implemented from a national perspective and are often widely distributed over large geographic areas. Any integration of these systems has been done, in design terms, from a “bottom-up” perspective.

- The current ATM System has humans at the centre of virtually all activities and this has been at the heart of providing safe, high quality air navigation services. However, expectations are that in some cases the human will not be able to deal with the future level of traffic and its complexity in the same way as it is done today. There is a need for a paradigm shift in the current concept of operations to break through the “capacity barrier” predicted to occur between 2013 and 2015 and to meet the future business challenges. This shift will include an increased use of automation to do some tasks traditionally performed by humans.

- Although en-route delay is at a historically low level and since capacity at airports is primarily the limiting factor of overall System capacity, it is unclear whether the potential for additional delays in the en-route sector are being “masked” by other factors. This should be investigated.

- Today's ATM System is predominantly centred on the use of ground-based systems, but much information and functionality exists in systems on-board the aircraft which can be significantly exploited to improve ATM performance both today and in the future.

- It is anticipated that the design of the future ATM System will, when viewed from the top down, have a functional architecture which defines the information flows needed between the principal entities which make up the System. Therefore, there will be one System design which incorporates both the ground-based and airborne systems, treating them as a whole.

- In the future, applied R&D must focus upon the applications needed to achieve System performance and then identify the technological solutions to deliver them.

It is considered that quite a number of short-term solutions can be found to overcome many current shortcomings, but for the medium and long-term it is essential to rejuvenate the ATM concept of operation according to performance needs and expectations by the air transport industry as a whole. The requirement is that the future ATM System consists of both the airborne and ground segments being designed to be integral parts of it, so enabling a holistic approach to be taken to grow air traffic safely and efficiently.

Expectations are that significant capacity gains will be obtained with the efficient use of advanced technology and improved airspace management. The shifting of roles and responsibilities within the ATM System then can be made to match the strengths of the human operator with the power of automation in a well balanced and carefully managed manner.

2.2 Future ATM System

The future ATM system described in the SESAR ATM Target Concept [D3] is based on the main principle that each flight shall be executed as close as possible to the intention of its owner. This Airspace User’s intention with respect to a given flight is represented by the business trajectory (for military “mission trajectory”). Air traffic management services which are necessary to execute this trajectory will ensure that it is carried out safely and cost efficiently within the infrastructural and environmental constraints. Changes to the business trajectory must be kept to a minimum, altering it only for reasons of separation and/or safety or in case the Airspace Users’ and ATM network goals (relating to performances in terms of capacity, environment and economy) are best met through maintenance of capacity and throughput rather than optimization of an individual flight.

In this context, the SESAR ATM Concept of Operations for 2020 represents a paradigm shift from an airspace-based environment to a trajectory-based environment with the following characteristics:

1. **Trajectory Management is introducing a new approach to airspace design and management;** Trajectory-based operations imply a new approach to airspace design and management to avoid, whenever possible, airspace becoming a constraint on the trajectories. Airspace User preferred routing, without pre-defined routes will be applicable everywhere, other than in some terminal areas and below a designated level in some areas.
2. **Collaborative planning continuously reflected in the Network Operations Plan (NOP);** Collaborative layered planning undertaken at local, sub-regional and European level will balance capacity and demand taking into account constraints and diverse events. Efficient queue management will allow optimized access to constrained resources (mainly airports). The results of these processes will be permanently reflected in a continuously updated Network Operations Plan ensuring a degree of strategic de-conflicting whilst minimizing holding and ground queues.
3. **Integrated Airport operations contributing to capacity gains;** Airports will become an integral part of the ATM system due to the extension of trajectory management. Increased throughput and reduced environmental impact (through e.g. turnaround management, reduction of the impact of low visibility conditions, etc.) is envisaged. With improved Airport Resource Planning processes there will be greater coordination between the stakeholders and thereby an improved use of available capacity to meet the increased demand.
4. **New separation modes to allow for increased capacity;** New separation modes gradually being implemented over time, supported by controller and airborne tools, will use trajectory control and airborne separation systems to minimize potential conflicts and controllers' interventions.
5. **System Wide Information Management – integrating all ATM business related data;** Underpinning the entire ATM system, and essential to its efficient operation, is a System Wide Information Management (SWIM) environment that includes aircraft as well as all ground facilities. It will support collaborative decision-making processes using efficient end-user applications to exploit the power of shared information.
6. **Humans will be central in the future European ATM system as managers and decision-makers;** In the ATM Target Concept it is recognized that humans (with appropriate skills and competences, duly authorized) will constitute the core of the future European ATM System's operations. However, to accommodate the expected traffic increase, an advanced level of automation support for the humans will be required.

The A^3 ConOps described in this document is in compliance with the SESAR target concept, however, from an operational view it goes beyond that what is envisaged by ICAO, NextGen and SESAR. The ICAO Global ATM Operational Concept has stated that in the future ATM system '*the pre-determined separator will be the airspace user, unless safety or ATM system design requires a separation provision service*'. SESAR and NextGen both incorporate the idea that the flight crew can act as separator, although they play down the idea that the predetermined separator will be the airspace user.

On the contrary, A^3 en-route operations are based on the assumption that flight crews are the sole separator from traffic and all other hazards given the appropriate infrastructure, equipment and training. In this context, A^3 contributes to the New Separation Modes aspect of the SESAR concept; however, it focuses on the target system, not on the transition phase related to the gradual implementation of new functionalities. At the same time, A^3 does not consider mixed operations including both ATC and airborne separated flights, as it is believed that this complex problem cannot be solved without a preceding detail design and analysis of both component subsystems. Besides the differences described above, the A^3 ConOps follows the SESAR ATM Target Concept and uses insight from the ASAS Thematic Network 2 project (ASAS-TN2), which is sponsored by the European Commission (Directorate General Research).

The main characteristics of the A^3 ConOps ATM system, which uses elements of the ASAS-TN2 concept of operation, include:

- A^3 will depend on a net-centric, System Wide Information Management (SWIM) environment, including both aircraft and ground facilities. It will include aircraft trajectories, surveillance data, constraints, aeronautical information of all types and meteorological data. All users will share a common picture of operational information allowing them to identify the course of action that is both feasible and best matches their needs.

- A^3 is inherently based on the Airspace User's preferences principle expressed in terms of the business trajectory. Airspace users should be able to adopt or generate the trajectory that best meets their objectives. Constraints will be imposed only for projected congestion, or for security, safety or environmental reasons. These constraints will be shared on the SWIM network, allowing users to adopt the course of action that is both feasible and best matches their needs.

- All aircraft in A^3 will be self-separating, so that the flight crews are operating without the supervision or support of a controller; that does not mean that they are invisible to the ATM system, nor that they are necessarily free to fly where they choose. ANSPs may monitor aircraft that are self-separating, e.g. for flow control, to anticipate the arrival of the aircraft in controlled airspace or simply for awareness, but will not have the ability or a commitment to control or intervene when self- separation fails.

- Automation will monitor the environment, detect conflicts and provide positive guidance to the pilots in the selection of a resolution.

- Communications will have evolved to the point where data-link will be the predominant means of communication. Voice will still be available but used mainly for emergency operations and as backup for time-critical communications.

- The premise for the airborne surveillance function is that it will be developed based principally on information received via direct Air to Air Data-link augmented by information coming from SWIM. The A^3 document is only concerned with the operational use of the function and as such does not describe the means of surveillance. Within the SESAR D4, it is anticipated that the implementation of either a second new Automatic Dependent Surveillance – Broadcast (ADS-B) link or a significant enhancement of the existing one is required to support self separation application.

- Aircraft will have to adhere to flow constraints and there will be distinct procedures for entering and leaving ATC Managed Airspace.

2.3 ATM Change Process

A change in the ATM System implies synchronized modifications of a combination of procedures, crew and staff working methods, airborne and/or ground systems, legislative and regulatory framework and supporting aeronautical data. Three approaches are possible to change systems: maintenance, modernisation (renewal of large parts of the system), or complete replacement. Due to the lack of modular design in the current ATM, the change of old systems generally implies a complete replacement or important modernisation with higher associated risks. This is a blocking point for the improvement of the overall ATM network.

The ground system transition generally implies parallel operation of the new and the old system, specific procedures during the transition period and a possibility of a prompt return to the previous situation in case of problems. The ground system transition can only happen in a specific operational time window (natural low traffic period and/or imposed reduced capacity). The airborne system upgrades are first certified and then made available for new aircraft. Existing aircraft will be retrofitted, when it is suitable for the aircraft owner, if the change is mandated or beneficial.

Considering the large number and differences of the ground ATM systems and aircraft flying in Europe, the ATM network cannot change in one step but only in a continuous manner system by system. The backward compatibility and standardization are of paramount importance to ensure the continuity of service with modified and unmodified systems.

Chapter II Concept of Operations

3 Airspace

3.1 Airspace Definition

The exclusion of ATC as a controlling entity in iFly has led to a redefinition of the airspace compared to the definition used by SESAR. The A^3 ConOps introduces the concept of Self Separating Airspace (SSA) where the separator is the airspace user.

- The A^3 airspace is divided into 3 categories:
  - ***Managed Airspace (MA)***: it is limited to High Density – TMA Areas and other dynamically designed zones (e.g. Restricted Use Airspace, Military Airspace).
  - ***Unmanaged Airspace (UA)***: all airspace where Air Traffic Control (ATC) services cannot be provided and the pre-determined separator is the Airspace User.
  - ***Self Separating Airspace (SSA):*** all airspace whose boundaries are defined in time and space by the dynamic allocation of Managed and Unmanaged airspace.

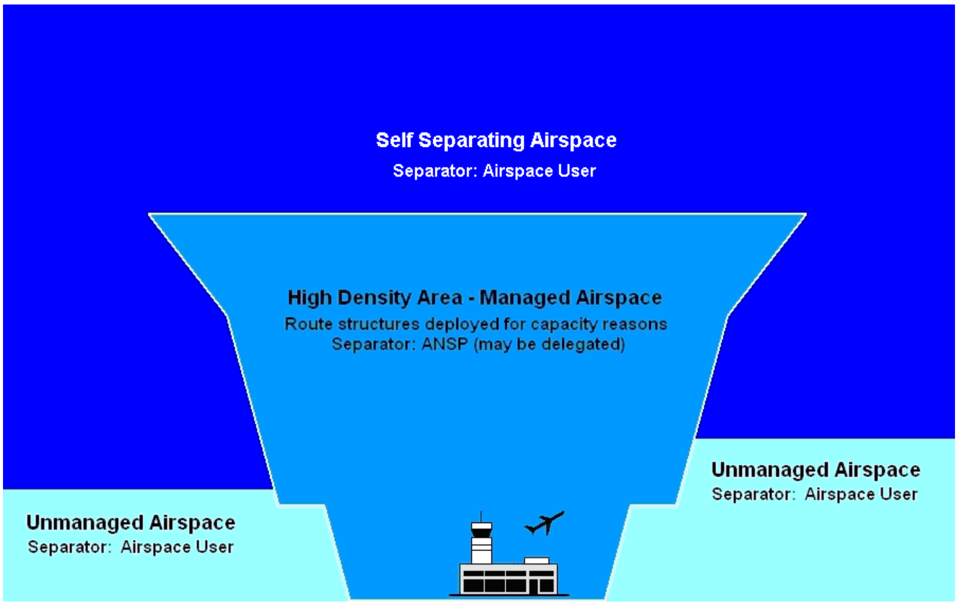

Figure 3-1 Airspace classification

- SSA requires that all aircraft are visible to the separator. This could be accomplished by both ground uplink and direct Air - Air Data Link.

- In SSA, Autonomous aircraft are responsible for separation, in accordance with pre-defined Autonomous Flight Rules (AFR) (see 8.4).

- In MA, all flights are subject to ATC clearances. Operations assignment – under Instrument Flight Rules (IFR), Visual Flight Rules (VFR), Night Visual Flight Rules

(NVFR), or Special Visual Flight Rules (SVFR) – and the associated separation responsibilities allocation will be managed by ground-based ATM.

- While not part of the A^3 ConOps, AFR operations may be conducted in UA, as long as Self Separation capable aircraft are certified and properly equipped to do so.

- In SSA, operations are conducted under AFR, while operations under Visual Flight Rules (VFR) will be allowed only below a given altitude (19 500 ft MSL for example).

- The A^3 en-route phase of flight of commercial and transport aircraft will entirely take place inside SSA[5].

3.2 Self Separating Airspace Structure

- SSA airspace may possess a ***flight level structure***; however, it ***will not be binding for AFR aircraft***, i.e. AFR aircraft are allowed to take whatever climbing/descent profile they may prefer, with the only limitations being the requirement of self separation, and the safety and comfort of the manoeuvres. Hence, there will not be any kind of hemispherical rule or any other similar static flow classification applied to AFR aircraft.

- ***User-preferred routing*** will be applied throughout.

- ***Restricted airspace areas*** (RAA) will be treated as non-moving conflict zones[6], with the same rules applying as with other aircraft conflict zones: AFR aircraft are responsible for maintaining the required separation with restricted airspace.

- ***Weather hazards areas*** (WHA) will be treated as slow-moving & changing conflict zones (for WHA outside the on-board weather radar sensor range a sufficient rate of weather information update from SWIM is needed to accurately reflect the dynamic changes of these zones). The same separation requiremens as for RAA apply to WHA.

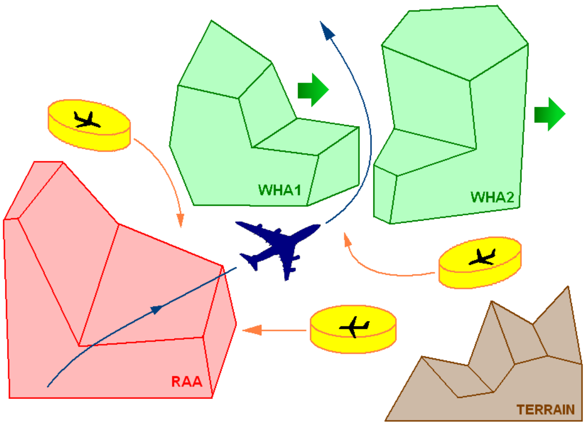

Figure 3-2 SSA conflict environment

- All conflict sources have their own characteristics that differentiate them operatively; however, the goal for a safe navigation is to avoid all conflicts, regardless of the nature of

[5] The 'en-route phase of flight' is considered in this ConOps to comprise the flight from the departing TMA to the arriving TMA.
[6] The possibility of moving RAA is considered for Emergency Operations; see 8.11.1

the area to avoid, be it Protected Airspace Zones (PAZ) belonging to other aircraft, RAA, WHA, terrain, or other obstacles.

3.3 Airspace Boundaries

- SSA is delimited, together with MA and UA, by dynamic allocation, in a service-oriented approach: the ANSPs will issue through SWIM the allocation of airspace, as part of the Collaborative Decision Making (CDM) flow management process with Flight Operations Centres (FOCs).

4 Assumptions

The Scope of the iFly A^3 ConOps is limited to en-route operations in which all aircraft are self-separating without involvement from ATC. Traffic Flow Constraints will exist at TMA entry fixes to regulate the traffic flow and to assist in the transition towards Managed Airspace (MA). The assumptions used in this ConOps include:

- An A^3 flight is defined as the flight between a departing TMA exit point, and an arriving TMA entry point, constrained by a Controlled Time of Arrival (CTA) at the arriving TMA entry point (Figure 4-1). Throughout the A^3 ConOps, the expression 'en-route phase of flight' will be used to refer to the A^3 flight definition.

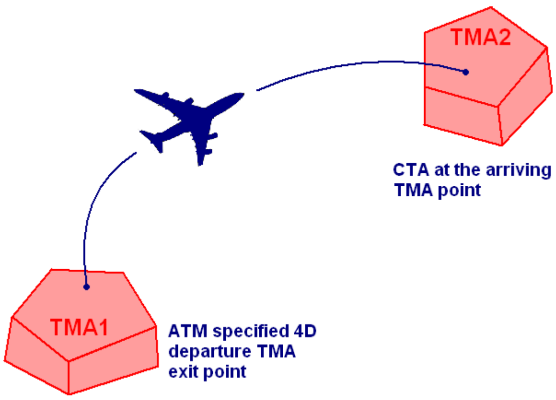

Figure 4-1 A^3 en-route flight

- Along this flight, the aircraft flies its Reference Business Trajectory (RBT), which is defined as the trajectory that the airspace user agrees to fly and the service provider agrees to facilitate, while:
    - Maintaining separation from all other aircraft and other conflict elements, and
    - Adhering to Traffic Flow Management constraints (CTAs).

- All aircraft are equipped and certified for self separation; this may include data link capability, Human Machine Interface requirements and support automation.

- Precision navigation will be standard. In particular, at least RNP 1 (equivalent to P-RNAV) navigation conformance is envisioned during self separation operations. This will facilitate adherence to intended (2D/3D) trajectories that provide predictability and consistency.

- The tasks regarding Conflict Prevention, Separation Assurance and Trajectory Management in SSA fall upon the aircraft crews, in the context of the A^3 ConOps.

- Within A^3 ConOps it is assumed that intent information will be available. The airborne system is designed to ensure self separation even without this data; however, in this case, the maximal attainable ATM performance will be different.

- Aircraft fly under Autonomous Flight Rules (AFR) (see Section 8.4).

- SSA may be monitored by ground/external surveillance systems, but no ATC separation services will be provided to the aircraft while inside.

- Operations in Unmanaged Airspace (UA) or transitions from/to UA will not be considered in this ConOps.

- Traffic Flow Management requirements for the transitions from SSA to MA (High Density – TMA) are described; however, detailed procedures concerning ATC during this transition will not be considered.

- The time frame for the A^3 ConOps is expected to be 2025+ (beyond SESAR scope).

5 A^3 enablers

- The A^3 ConOps enablers are those elements that allow for the succesful operations under the A^3 ConOps. The A^3 enablers include:
    - System Wide Information Management System: SWIM
    - Air-Ground and Air-Air Data Link Communications and Surveillance Broadcast
    - On-board Decision Support Tools (including ASAS)
    - Advanced Airborne automated applications
    - Advanced Ground surveillance support which allows for:
        - Communicating the presence of other aircraft in the aircraft's awareness zone, and
        - Detecting complex and/or congested areas
    - Advanced Human Machine Interfaces
    - New Procedures
    - Flight Management System
    - Airborne Collision Avoidance System (ACAS)

- The A^3 ConOps foresees the availability of a System Wide Information Management network which will provide all stakeholders with the data they need to perform any given tasks in a timely, reliable and accurate manner.

- The means envisioned to obtain information on surrounding aircraft is primarily through Air-Air Data Link (e.g.,. ADS-B). Data for aircraft outside the detection range (as current for ADS-B ~100-200NM) can be obtained through SWIM, for that the ConOps foresees an Air-Ground Data Link with SWIM ATM ground support services.

- All A^3 airborne systems are designed as on board decision support tool, i.e., tools that aid fligth crew in the decision making process, (e.g., conflict detection and resolution, strategic trajectory management) and thus will contribute to the safe and efficient operation of the aircraft. These tools will monitor the environment, alert the crew of possible conflicts and provide resolutions when necessary.

- Advanced airborne automation is foreseen to improve Situational Awareness (SA) and aid in the decision process. These applications will include new weather data fusion applications, warning functions and guidance algorithms.

- Advanced ground surveillance support functions will inform aircraft of other proximity traffic that can be of influence to the flight. Furthermore these functions can also provide information on complex and/or congested areas. All information will be available through SWIM.

- The new functions foreseen in the A^3 ConOps will require an appropiately designed Human Machine Interface to obtain the required level of Situational Awareness (SA) and to aid in the decision making process.

- New procedures and flight rules will be required to operate under the A^3 ConOps, these include the rules for autonomous operations.

- The A^3 ConOps foresees the use of a future Flight Management System that is integrated with the Decision Support Tools (DST) for autonomous operations.

- ACAS will be part of the A^3 ConOps and will serve as a safety backup.

6 Basic Flight description

- Prior to an A^3 flight, the following actions will have taken place:
    - Pre-flight Strategic Flow Management will have provided a strategic deconflicted[7] Shared Business Trajectory (SBT) for a given day.
    - Start of flight execution: taxiing, take off and flight through the departure TMA. This phase of flight is out of scope of this ConOps and is not described in this document. As soon as the take off time is known, a RBT is generated from the up-to-date Shared Business Trajectory.

- From then on, a normal A^3 flight will proceed as follows (see Figure 6-1 for reference):
    1. The Aircraft exits the departure TMA and enters SSA. At this point:
        a. The departure TMA ATCo has made sure that the aircraft is conflict-free (up to a TBD[8] look-ahead time, e.g. 10 minutes) from all other aircraft in SSA.
        b. The aircraft RBT is active, up-to-date and known to all SWIM-users.
        c. The aircraft has a CTA assigned at the arriving TMA by its ANSP, along with a time conformance window that is a function of the flight characteristics.
        d. The aircraft becomes autonomous and has to operate according to AFR rules (see section 8.4).
    2. The aircraft flies its preferred RBT, as provided by the FMS. The aircraft is performing the following communications and surveillance functions throughout:
        a. Broadcast of its own state and intent, separation class[9] and priority level through Air – Air DL.
        b. Updates of its own state and intent, and RBT to SWIM.
        c. Receiving and integrating other aircraft state and intent information from Air –Air DL or SWIM to achieve traffic SA.
        d. Communicating through SWIM for weather, forecast and area updates where applicable data will be fused with data from onboard sensors.
        e. Communicating through SWIM with its Flight Operations Centre (if the aircraft is operating with a FOC) to allow for airline fleet monitoring.
    3. The arriving CTA may (through datalink) be (re-)negotiated by the flight crew or entry TMA controller:
        a. The CTA can be renegotiated by the flight crew to reflect the course of the flight (i.e. not able to maintain)
        b. The CTA can be renegotiated by the TMA controller for the purpose of flow management (i.e. different desired sequence).
    4. Upon arriving at an Arrival Manager (AMAN) capable TMA (~100-200 NM before Metering Fix) the aircraft will lock into the AMAN system, which will:
        a. Sequence all arriving aircraft.
        b. Issue a CTA with a fixed required time for TMA entry[10].

---
[7] Traffic flows that have no conflicts by design
[8] This time would be part of a specific research aimed to define it, out of the A3 ConOps scope.
[9] Distinction in separation minima (i.e. 7 Nm vs. 5 Nm) to indicate current CNS capability or to accommodate special flight operations (military, head-of-state etc.)

In addition:

c. The onboard system will increase the ‘priority’ level and broadcast this to other aircraft, so that it has priority over other, non-TMA approaching aircraft (departures, en-route aircraft).
d. The responsibility for separation with other aircraft remains with the flight crew, but the design of TMA entry points (both in space and time) should in principle allow the aircraft to ensure separation from other traffic while being able to conform to its CTA.
e. The aircraft may also be given a Traffic To Follow (TTF) and Spacing Interval (SI) to enable airborne spacing.

5. The aircraft reaches the arriving TMA in compliance with its CTA at a predefined TMA entrance point, and conforms to the Air Traffic Management requirements inside the arriving TMA. When entering the TMA the aircraft will cease to perform self separation and will again be controlled by ATC.

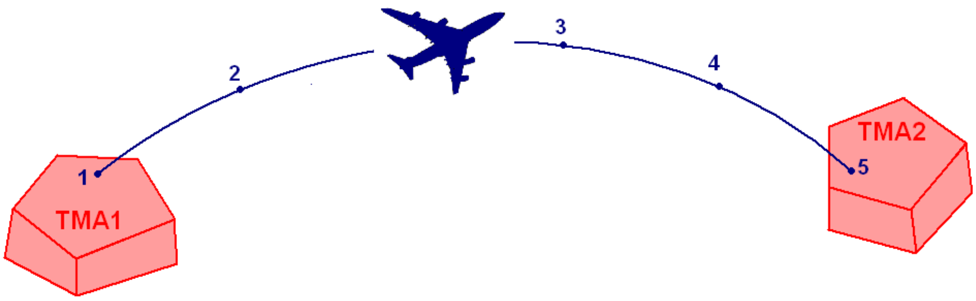

Figure 6-1 Reference Figure for a basic flight description

[10] For non AMAN capable TMA’s, the CTA will be issued through SWIM by CFMU or the controlling entity of that airspace.

7 Pre-flight Strategic Flow Management

- The aim of Pre-flight Strategic Flow Management is to provide a structure to the airspace, which is strategically de-conflicted. This means that for each flight the entire Shared Business Trajectory (SBT) is scheduled to be 'a priori' traffic conflict-free[11], and also free of areas (in space and time) where the air traffic complexity or congestion reach unacceptable levels for the normal course of the operations. This does not imply that once the aircraft start flying, there will be no conflicts in the Reference Business Trajectory (RBT). The goal is merely to prevent conflicts by design.

- The following pre-flight actors are considered:
    - Flight Operations Centres[12] (FOC)
    - Non-FOC Airspace Users (NFU)
    - Air Navigation Services Providers (ANSP)

- The pre-flight actors in the A^3 ConOps are those entities and/or organisations that, from the user's perspective, contribute to the development of the Shared Business Trajectory (SBT), as defined in SESAR D3 document.

- The SBT will contain all the pre-planned flight trajectory data, from take-off to landing, ideally being integrated with the taxiing and handling processes in a gate-to-gate ATM concept.

- The A^3 ConOps only focuses on the en-route phase of flight, therefore in this document 'SBT' is used to refer only to that phase of flight.

- The part of the SBT that takes place in the en-route phase of flight expresses the user's preferences, but it does not result in any obligation on the airspace user to conform to it while actually in-flight. Other parts of the SBT, which may involve a contract between the ANSP and the airspace user, are not discussed in this ConOps.

- Pre-flight actors will express their preferences for a given flight by issuing a SBT request to the Air Traffic Authorities[13], and by negotiating in a CDM process. The, resulting SBT will be published in SWIM, and made available to all airspace users and ANSPs.

- The CDM process, which takes place in the development of the Network Operations Plan (NOP), as defined in SESAR, must take place involving ANSPs, FOCs and NFUs to refine the SBTs and determine the 4D points (location and Controlled Times of Arrival (CTAs)) that concern the flight in the SSA:

[11] Traffic flows that have no conflicts by design

[12] Flight Operation Centre is a generic term covering Airline (or Wing) Operation Centre (FOC) ATM and Airspace User agent (SESAR D5 – SESAR Master Plan, ref. DLM - 0710 - 001 - 02 - 00 April 2008; web address: http://www.sesar-consortium.aero/deliv5.php).
The Flight Operation Centre is focused at aircraft routing, scheduling, and disruption recovery to handle the irregularities During the tactical phase of the aircraft operations the Flight Operation Centre (FOC) centre makes coordinated decisions regarding the operations taking into the account the constraints and available resources within the supporting groups.

[13] Organization(s) in charge of Flow Control

- High Density – TMA exit point at the flight's departure
- High Density – TMA entry point at the flight's arrival

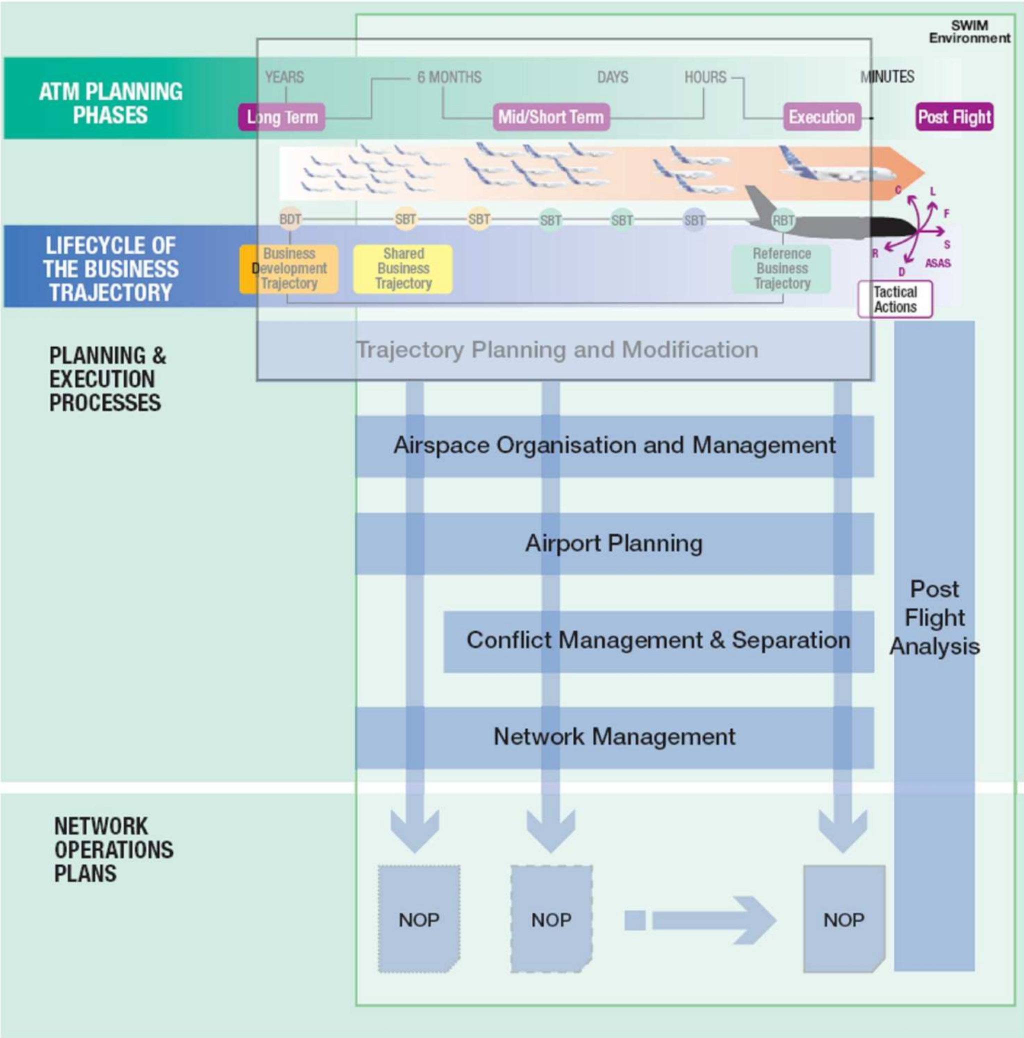

Figure 7-1 Network Operations Plan Structure (SESAR D3: ATM Target Concept)

- NFUs will also be introduced in the SBT determination process, by issuing SBTs which must take into account the FOCs, NFUs and ANSPs CDM process. They will be integrated in the ATM organization by ANSPs, since they might lack the infrastructure that airlines possess to participate in the high-level CDM process. Nevertheless, a certain degree of negotiation might be conducted between ANSPs and NFUs, in order to provide them with the greatest possible degree of satisfaction to their SBT demands.

- The resulting SBT arrangement should ensure:
  - 'A priori' conflict-free trajectory from TMA exit to TMA entry.
  - Avoiding the creation of zones of excessive en-route complexity.[14]
  - A reasonably good achievement of the interests of the FOCs and NFUs, with the ultimate goal of allowing them to operate without ANSP dependence.

[14] Only a static distribution of aircraft trajectories is considered at this pre-flight level.

- That once the actual RBTs are issued, it is possible to provide CTAs for the arriving TMAs, that will ensure smooth operations for the airports and also meet the requirements of the airspace users to the greatest possible extent.

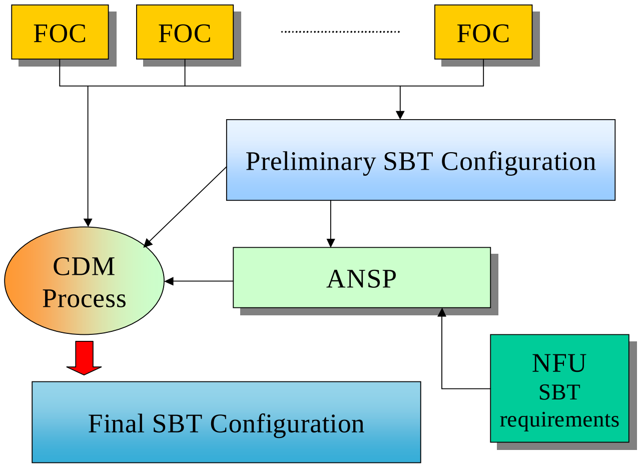

Figure 7-2 Pre-flight CDM Process

7.1 Flight Operations Centres

- FOCs are responsible for the safe planning and conducting of their own airliners' flights, with the goal of providing operational benefits to the airline. The roles of the FOCs are involved with ***Strategic Flow Management*** and with ***In-flight Traffic Monitoring***:

7.1.1 FOC involvement with Strategic Flow Management (SFM)

- FOCs goal is to provide the SBTs of the flights of their fleet to be executed in a given time period (e.g. daily).

- FOCs will take into account airport slot assignment and their own commercial interests to create a preliminary version of the preferred SBTs for their flights. Free Scheduling when possible is at this stage the norm.

- The main focus for airlines is in meeting time demands: estimated times of arrival are the main parameter of the SBT negotiation at this level, together with efficiency, economy and time-saving considerations.

7.1.2 In-flight Traffic Monitoring by FOC

- FOCs will track the operation of their fleet through SWIM:
    - For performance analysis and economic assessments
    - To support their aircraft for the purpose of flow management; from a strategic point of view (to avoid congested areas) but also from an operational point of view
    - To co-ordinate departures and arrivals with ANSPs

    - To evaluate contingency and emergency situations and be able to assess and adjust accordingly in near-real time

- Data Link communications will be the primary means of communication with their aircraft and will allow FOCs to update RBT-related information for SFM issues or in the case of a contingency/emergency situation.

- A voice channel will be maintained for emergency purposes.

- For those aircraft operating with FOC, the normal course of the operations will be carried out under two-way data exchanges between the aircraft and their FOCs.

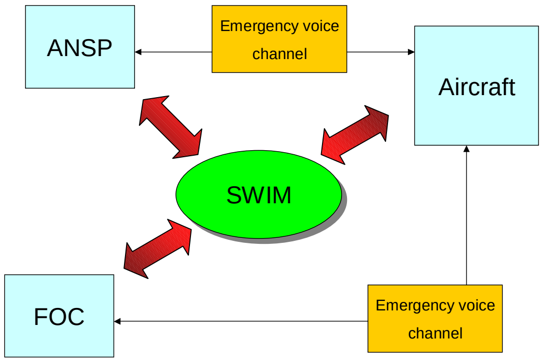

Figure 7-3 In-Flight Traffic FOC Monitoring Scheme

7.2 Non-FOC Airspace Users

- The SBT CDM process is also available to NFUs. However, due to the limitations in their operations, NFU's might opt to collaborate with FOC-operating airlines to receive the benefits of the full system.

- NFUs may include:
    - Charter and Low-Cost airlines that lack the resources for a FOC
    - Business jets, operating privately or in companies
    - General aviation operating in SSA
    - Military and official aircraft

- In some cases, certain NFUs can be offered privileges, especially in the case of military and official operations, in order to allow them to perform a specific mission.

7.3 Ground Support

- While ATC is not a controlling entity in the A^3 ConOps, other ground-based actors are required for SFM and flight support. This maintains the notion that this ConOps is ground supported, however, without the presence of ATC.

- The role of Ground Support in the A^3 ConOps concerns:
    - Pre-flight Strategic Flow Management.
    - Transition Operations from MA to SSA and vice versa.
    - The support services that are defined in the A^3 ConOps for the aircraft to achieve an adequate situational awareness.

- A major role will be provided by SWIM, which will serve as the primary source of information for flight optimization and long term area avoidance.

- Ground support tools that enable SWIM to transfer aircraft information for traffic relevant to the own ship but which resides outside the aircraft detectable range.

- SWIM will also play a major role during Non-normal and Emergency operations.

7.3.1 ANSPs at Terminal Airspace Area

- It is recognized that it is not possible to coordinate the overall SBT configuration when regarding departures from/arrivals at TMAs without the participation of the Air Navigation Services Provider that manages the TMA.

- ANSPs at TMAs will be considered as the Air Traffic Authority when there is need for arbitration regarding SBT proposals that are conflicting in their TMA.

- However, the role of ANSPs at TMAs is limited to pre-flight SFM aspects and NOT separation management during the autonomous part of the flight. The main instrument for SFM will be the assignments of entry constraints at the arrival TMA. This constraint (in the form of a CTA) will be uploaded to the aircraft via SWIM. During the flight this constraint can change in accordance with the course of the flight (see Section 6).

7.3.2 ANSP involvement in Transition Operations

- An ANSP of neigbouring Managed Airspace (MA) will participate in the transition operations as a natural consequence of their ATM responsibilities inside MA; although the A^3 ConOps does not describe transition operations in detail, there are some rough guidelines given Section 8.9.

7.3.3 Support Services

- The allocation of airspace for special uses (Restricted, Military Airspace, etc.) will come from national or trans-national authorities; the same will apply to sources of meteorological & hazards information. The main channel for communication with these sources will be SWIM.

- Data from support services will also be used by flight crews to make changes to their active RBT.

8 Autonomous Flight Operations

The flight operations in which the flight crew has responsibility for self separation and is required to operate according to specific autonomous flight rules are defined as Autonomous Flight Operations.

- Autonomous Flight Operations will be considered under the following circumstances:
    - ***Normal Operations***: all equipment is functioning nominally and the flight crew is able to perform their ATM functions as required.
    - ***Non-normal Operations***: there is a degradation in any, several or all:
        - On-board equipment performance
        - Flight crew performance
        - SWIM network performance
        - Aircraft performance

      in a given (or various) aircraft, but the remaining performance of the overall system is such that self separation operations under the A^3 ConOps can be maintained, while the safety requirements are also kept.
    - ***Emergency Operations***: there is a degradation in any, several or all:
        - On-board equipment performance
        - Flight crew performance
        - SWIM network performance
        - Aircraft performance

      in a given (or various) aircraft that does not allow for the continuation of operations under the A^3 ConOps, while retaining the accepted safety levels. This may include severe Surveillance - Broadcast capabilities loss in one or more aircraft, SWIM, Air - Air or Air - Ground data link performance degradation, or a hazard of such magnitude that it is not possible to maintain the required safety level in the operations; the main goal of the description of emergency operations is to delimit up to which point the autonomous A^3 operation can be continued, rather than establishing the procedures in these cases.
    - A Minimum Equipment List (MEL) for autonomous operations can aid in the determination of the appropriate flight condition. It lists the instruments and equipment that may be inoperative without jeopardizing the safety or capabilities of the aircraft. It is developed for a specific aircraft and type of operation and is approved by the appropriate authority (the FAA for civil registered aircraft in the United States, EASA for civil registered aircraft in Europe, etc). It also includes procedures for flight crews to follow when securing or deactivating inoperative instruments or equipment

8.1 Flight crew roles, tasks and responsibilities

- The flight crew is responsible for the safe, efficient and on-time operation of the flight. Within this task the flight crew will have to:
    - Conduct any pilot-initiated trajectory changes or manoeuvres provided they are clear of conflicts.

  - Change trajectory as proposed by automation system in accordance with alert levels and associated procedures
  - Operate aircraft within established parameters of the automation system

- The flight crew is responsible for separation with all other aircraft and adhering to flow management constraints.

- During the self separation part of the flight, the flight crew will have the following new and/or modified responsibilities:
  - Strategic conflict management
    - Avoidance of high complexity areas
    - Avoidance of WHA and RAA
    - SFM constraints (CTA/RTAs) compliance
    - Overall trajectory optimization
  - Separation provision:
    - Avoidance of traffic separation losses
    - Avoidance of high complexity areas
    - Avoidance of WHA and RAA
  - Collision avoidance
  - Monitoring of data communications.

- Although there is a number of modified or additional new functions to be performed, preliminary human factor studies and simulation [23] on 3 to 6 times current day traffic densities have shown that, with proper automation assistance, they are not expected to represent an unmanageable increase in current flight crew workload during the en-route phase of flight.

- In addition, the workload that results from the performance of these extra functions is offset by a reduction in several tasks that currently pose a rather heavy burden in flight crew workload:
  - Voice communication.
  - Radio frequency changing and sector monitoring.
  - Achievement of nearby traffic situational awareness through radio communications monitoring and ‘out of the window’ viewing.

- The flight crew will have new Decision Support Tools which will help reduce mental workload. Traffic & navigation-related information will be displayed through a Human-Machine Interface (HMI) that allows for quick and easy decision making, and easy manoeuvre implementation. The design of the Decision Support Tools will give each crewmember usable, flexible and informative means for supporting SA and aid in their specific decision making task.

- The primary guidance mode of operation will be through a Flight Management System and fully automated. Crews may (at their own choosing) opt to disconnect from the FMS, however this will reduce the system capability (e.g., the available look-ahead time for conflict detection will be reduced, which will limit medium and long term conflict resolution). This also applies to aircraft that fly without FMS equippage.

- The flight crew will manage the flight at different levels:

1. Overall flight SFM constraints compliance: the goal of any given flight is to meet its assigned CTA at the specific TMA area entry point. This objective sets up the whole ATM operation performed throughout the flight; trajectory management has to consider the corresponding adjustments in course, altitude and speed to allow the aircraft to maintain CTA requirements.
2. Strategic/Long term area conflict detection and avoidance and trajectory management: SWIM will provide the flight crew with airspace information, meteorological data and weather hazards, so that it is possible to consider these aspects in long-term trajectory planning.
3. Tactical/Medium term conflict detection and avoidance: using traffic intent and state information from Air – Air DL and supplemented by SWIM.
4. Short term conflict detection and avoidance.

- An ACAS system will act as an back-up system and independently of in-flight ATM functions.

- If a flight crew for whatever reason is not able to perform their self separation task, the tasks involving separation assurance will fall upon nearby aircraft (the inability to perform self separation could be indicated by means of a transponder code, ADS-B flag or based on time to LoS).

8.2 Conflict environment

- A conflict occurs when an aircraft Protected Airspace Zone (PAZ), which is described in Section 8.3, is predicted to be penetrated by:
    - A Restricted Airspace Area (RAA).
    - A Weather Hazard Area (WHA).
    - A Terrain/Obstacle restriction.
    - Other aircraft.

- In other words, a conflict does not imply that Loss of Separation (LoS) has already occured but it implies that a LoS will probably occur if no action is taken.

- Look-ahead times for Conflict Detection (CD) may differ according to the information used, but most commonly lie between 3-5 min for State based CD and 15-20 min for Intent based CD.

- It is important to note that the process of detecting and resoving conflicts is part of the normal operations performed by a self separating aircraft; the appearance of a conflict does not indicate a non-normal or emergency situation.

8.3 Aircraft separation - Protected Airspace Zone (PAZ)

- PAZ represents legal separation requirements and is defined as a vertical cylinder centred in the aircraft.

- A Loss of Separation (LoS) occurs if the lateral and vertical distance between two aircraft is less than the PAZ dimensions. In other words, while PAZ zones may overlap, aircraft may not enter the PAZ of other aircraft.

- The EC-TREN Reduced Separation Minima (RESET) Project has indicated that while a reduction in Separation Mimima (SM) may increase the available airspace capacity, controller workload and not separation between aircraft is the limiting factor for en-route capacity growth. Furthermore, wake vortex influence and Human Factors (among other issues) also need to be investigated before a reduction in SM can be considered. Reductions proposed by RESET Project for en-route aircraft minumun separation are:
    - *Longitudinal Separation*: from 5NM to 3NM
    - *Vertical Separation*: to 900 ft **(**between FL290 and FL410)
    - *Lateral Separation*: to 5NM (between fixed routes/dynamic routes/ reference trajectories)

- For the expected timeframe of the A^3 ConOps, it is likely that the reduction in SM would have been investigated and implemented; therefore, it was decided to implement different SM criteria for the:
    - ***Comfort Separation Zone (CSZ):*** the volume around the aircraft that is used for separation assurance, which provides additional margins for maintaining separation with the Minimum Separation Zone, even in the presence of uncertainties.
    - ***Minimum Separation Zone (MSZ):*** it represents the volume that another aircraft cannot penetrate in order to maintain the safety levels considered in A^3 ConOps Operations.

- For the PAZ dimensions it is not yet sure whether the RESET based reduction makes it physically possible to increase the en-route traffic capacity by more than a factor two. These dimensions are defined (in agreement with EC-RESET project) as follows.:
    - Horizontal: 5 NM radius CSZ, 3 NM diameter MSZ
    - Vertical: 1000 ft half height CSZ, 900 ft half height MSZ

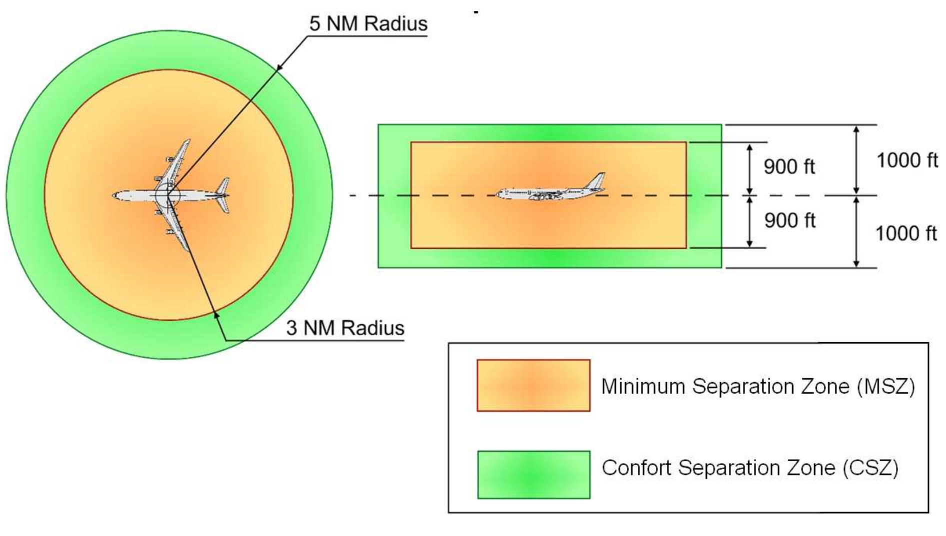

Figure 8-1 Protected Airspace Zone

- On-board ASAS systems are required to detect and resolve any conflicts (predicted LoS) with the PAZ Comfort Separation Zone. Loss of Separation with the Minimum Separation Zone should at all times be prevented.

- The A^3 ConOps does not provide a definition for a Collision Avoidance Zone (CAZ), as collision avoidance functionalities are provided through ACAS.

- In order to accommodate military or special flight operations it might be necessary to include different separation classes with individual separation standards. This needs further study.

- Individual separation classes will be broadcasted and also made available through SWIM.

8.4 Autonomous Flight Rules

- Autonomous aircraft (Aircraft that operate in SSA and that perform self separation) have to abide to the following rules:
    - Autonomous aircraft are responsible for maintaining separation with all other aircraft.
    - Autonomous aircraft are required to maintain separation from designated areas and no-fly zones.
    - Autonomous aircraft are required to adhere to flow management constraints. Renegotiation will have to take place if these constraints can not be met.
    - Lower priority autonomous aircraft involved in a medium term Intent based conflict ruled by priority are required to manoeuvre to solve it sufficiently in advance, so that the conflict does not continue until the conflict resolution becomes a short term cooperative conflict.
    - Autonomous aircraft shall not manoeuvre in a way that creates a short term (3 to 5 minutes) cooperative conflict.
    - The trajectory of autonomous aircraft shall at no time place the aircraft in a 2 minutes state vector conflict (blunder protection).
    - Autonomous aircraft shall not enter Managed Airspace without the approval of the controlling entity of that airspace.

8.5 Surveillance/Awareness zones

- One of the difficulties of an autonomous aircraft concept is the limited availability of information about the surrounding environment. This is due to a limited range of airborne sensors (Weather Radar - WXR ~200-300NM) and in case of air traffic also a limited range of direct air-air communication (e.g., ADS-B ~100-200 Nm). The A^3 ConOps proposes a system that aims to overcome these limitations and provide a safe and efficient ATM system.

- Within A^3 each aircraft will provide three levels of surveillance information regarding own flight:

1. **State data** – current position and velocity vector, priority level and separation class, broadcasted independently through data link (e.g., ADS-B). Update rate is in the order of seconds.
2. **Intent data** – trajectory change and conformance monitoring data broadcasted through data link[15] and also provided to SWIM[16]. A^3 does not define the contents or format of the intent message as this is already a subject of intensive research in the ATM community (e.g., AP16). However, it is assumed that this data enables a reconstruction of the predicted actual 4D trajectory for given amount of look-ahead time (~10-20min) with the accuracy specified by a conformance boundary (estimated conformance parameter(s) (reflecting, e.g., the actual navigation performance) being a part of the intent message). The Intent data is regarded invalid if aircraft operates outside conformance boundaries. Update rate for the complete intent data is in the order of tens of seconds.
3. **Reference Business Trajectory (RBT)** – planned 4D trajectory provided to SWIM and FOC (if available). Based on State and Intent data and augmented with planned route data, this information is not used by other airborne systems; however, it can be used for dynamic on-board trajectory optimization.

- The purpose of the different levels of surveillance information is to provide an accurate prediction of the aircraft state and future positions. However, the credibility of the resulting trajectory information will differ considerably depending on the dataset used. Three timeframes are defined in relation to the predominant type of data employed:
  1. **Short term timeframe** – typically up to 3-5 minutes, represents the time horizon up to which the trajectory obtained by a state-based extrapolation may still represent a reasonable approximation.
  2. **Medium term timeframe** – typically up to 10-20 minutes, represents the time horizon up to which the trajectory can be reconstructed from intent data.
  3. **Long term timeframe** – typically more than 30 minutes, represents the time horizon used for dynamic on-board trajectory optimization. Only RBT-based data may provide useful information about flights in this timeframe.

- Safe A^3 operations require a continuous availability of all relevant information of the aircraft environment. In this context:
  - It is assumed that traffic information related to the short-term timeframe will be obtained through direct air-air communications.
  - For medium and long term time horizons, it is anticipated that an important amount of information will be provided through SWIM. The **Awareness Zones** are dynamically defined to enable processing of relevant information.
    1. **Medium term Awareness Zone (MTAZ)** covers aircraft environment for the medium term timeframe of its flight.
    2. **Long Term Awareness Zone (LTAZ)** covers aircraft environment for the long term timeframe of its flight.

- An important operational difference between the MTAZ and the LTAZ is that:
  - Airborne self separation is performed only within the MTAZ.

[15] Air-Air data link (ADS-B) is the primary means of obtaining Intent data

[16] Intent data of aircraft that are not within ADS-B range and are of interest to the aircraft will be obtained through SWIM

  - The Long Term Awareness Zone is used for flight optimization and flow management.

- Note, that the Long Term Awareness Zone is not defined as a complement to the Medium Term Awareness Zone but as an overall encompassing area, i.e., including the space of MTAZ.

- Figure 8-2 depicts an overview of the proposed Surveillance Hierarchy. The configuration and range of LTAZ is yet to be defined, but will not exceed the border of SSA. They will depend basically on the availability of long term information.

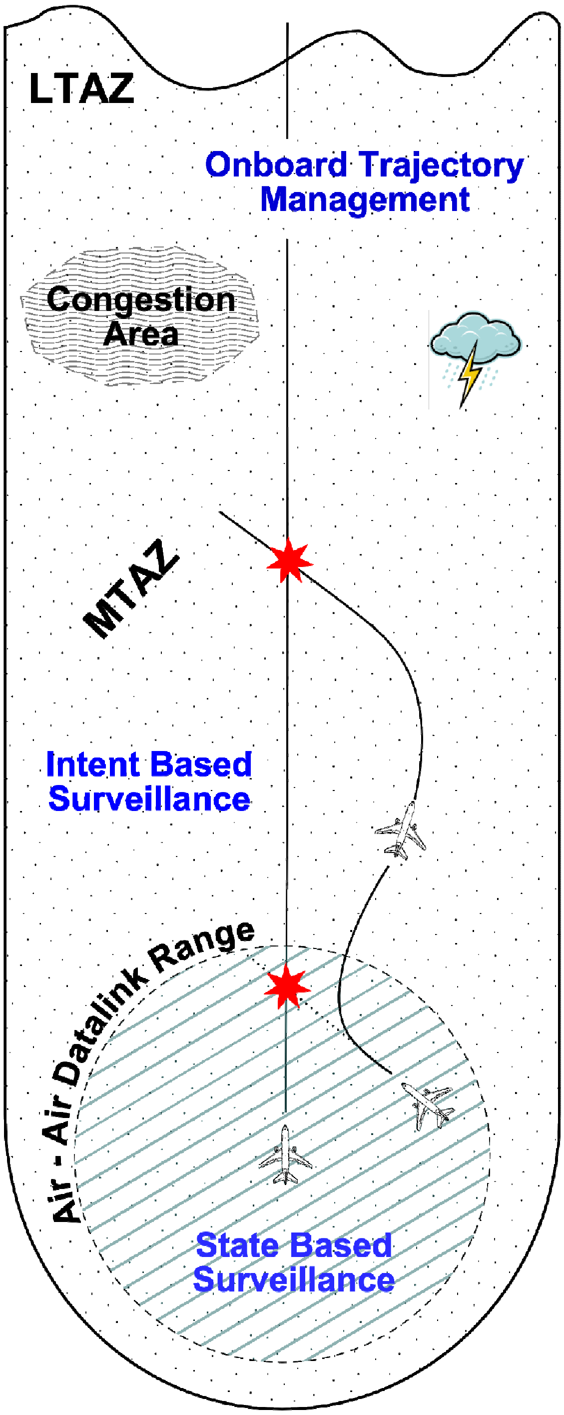

Figure 8-2 Surveillance Hierarchy Overview

8.6 Conflict Detection and Resolution

- The following table summarizes all the Conflict Detection and Resolution (CD&R) and ACAS modules considered within the A3 ConOps:

	Look ahead time for CD	Coordination	Principle of use	Priority Rules	Do not create secondary Conflict	Type of resolution algorithm
LTACD[17]	>30 min	Not applicable	RBT	Not app.	Not app.	No resolution
MTCD&R[18]	Up to 15 to 20 min	Not required	Intent	YES	Do not	Intent Based
STCD&R[19]	Up to 3 to 5 min	Implicit	State (1st level of intent)	NO	Do not	1 on N
ACAS	< 1 min	Explicit	Pure State	NO	Try not	1 on 1

- The 'Look ahead time for CD' relates to Conflict Detection and is not an indication of what CD&R module to use for resolution. For example, a conflict can be detected by the MTCD module (intent conflict), but require a short-term resolution[20] and therefore be solved by the Short Term CR module. All CD and CR modules work in parallel, and the Conflict Processing module may assign conflicts coming from any CD module to the appropiate CR module.

- The coordination is expected to be:
  - Explicit (i.e. handshaking[21]) for Collision Avoidance.
  - Implicit for Short Term Conflict Resolution (by use of similar algorithms and rules).
  - Not Required for Medium Term Conflict Resolution when using priority rules.
  - Not applicable to Long Term Area Conflict Detection.

- Priority rules determine which aircraft has the right of way and which aircraft has to manoeuvre.

- The types of resolution algorithms[22] considered include:
  - "Intent based": resolve all conflicts and provide a resolution that is conflict free up to a TBD time (e.g.,10 min) beyond the look-ahead time.

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[17] LTACD: Long Term Area Conflict Detection
[18] MTCD&R: Medium Term Conflict Detection and Resolution
[19] STCD&R: Short Term Conflict Detection and Resolution
[20] Whether or not an Intent conflict requires a short-term resolution is determined by time to LoS.
[21]**Handshaking** is an automated process of negotiation that dynamically sets parameters of a communications channel established between two entities before normal communication over the channel begins. It is a predetermined hardware or software activity designed to establish or maintain two machines or programs in synchronisation. Handshaking often concerns the exchange of messages or packets of data between two systems with limited buffers. (The Free Dictionary, http://www.thefreedictionary.com/)
[22] These algorithms are used in the different scenarios defined. Paragraph. 8.6.1, 8.6.2, 8.6.3, 8.6.4

- "1 on N": resolve all instantaneous conflicts without further requirement of remaining conflict free beyond the look-ahead time.
- "1 on 1": in case of multiple conflicts resolve the most critical conflict first.

- Algorithms that can provide functionality beyond the required minimum will be preferred.

- CR algorithm implementations should allow for the inclusion of user preferences and provide useful alternatives in case pilots reject the provided solution.

- Traffic separation assurance is only applied within the MTAZ, using all available CD&R modules. Conflict information from the CD modules will be fed into the Conflict Processing module which will determine the urgency of the situation and consider the appropriate resolution module.

- One of the AFR rule implies that the aircraft trajectory can at no time place the aircraft in a 2 minute state vector conflict with another aircraft, this requires that algorithms have to check the extended state vector at Trajectory Change Points (TCP) for possible state conflicts.

- All CD modules work in parallel and therefore a conflict can be detected simultaneously by both Medium Term CD as well as Short Term CD. The information from both detection modules will be provided to the Conflict Processing unit which will determine the appropriate CR module.

- An alert level will be issued by the Conflict Processing unit based on the time to Loss of Separation. Each alert level will be associated by a different attention getter (aural or otherwise)

- In the following, each CD&R module is described. In the explanatory diagrams that come with each description, the following color coding has been established:
    - **Dark Grey:** long term trajectory information (aircraft flight path / RBT).
    - **Green:** medium term trajectory information (aircraft intent, up to 15 – 20 minutes look-ahead time).
    - **Yellow:** short term trajectory information (aircraft first level of intent[23] and/or aircraft state, representative up to 5 minutes look-ahead time).
    - **Red:** ACAS (pure state, 1 minute look-ahead time).
    - **Blue:** extended 2 minute state vector projection. A double-headed arrow is used to differentiate this from planned airplane trajectories.

[23] Level of Intent can be: a) target state, b) one Trajectory Change Point (TCP) or c) full intent (multiple TCP's).

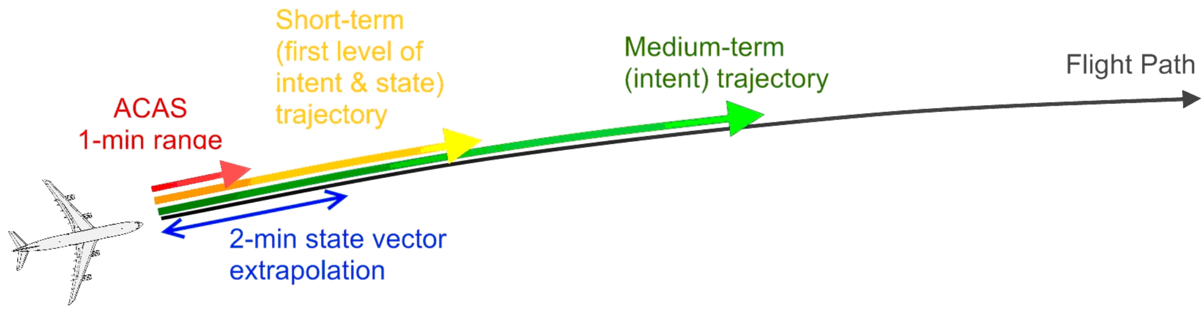

Figure 8-3 CD&R Colour coding

8.6.1 Long Term Area Conflict Detection (LTACD)

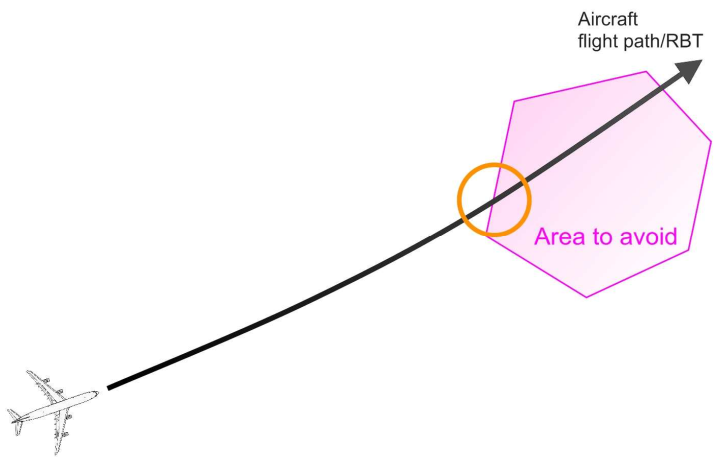

Figure 8-4 Area Conflict

- The Long Term Area Conflict Detection functionality will apply to the LTAZ and detect any conflicts with "areas to avoid". The crew will be informed of these conflicts so that appropriate action can be taken[24].

8.6.2 Medium Term Conflict Detection & Resolution (MTCD&R)

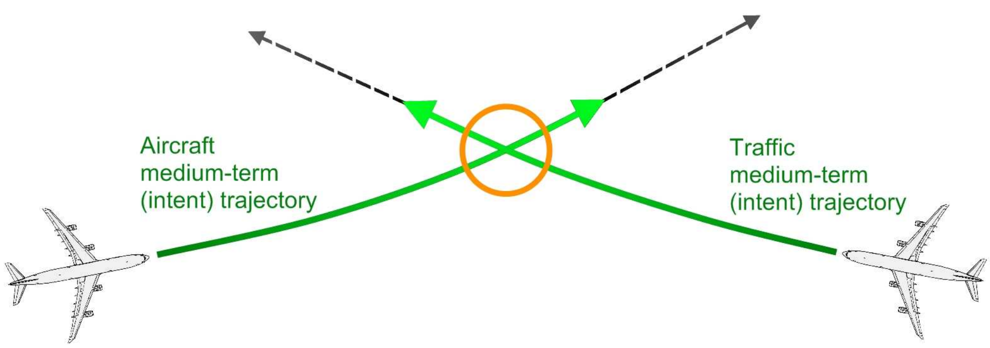

Figure 8-5 Medium Term Conflict

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[24] Resolution will be provided by TM module.

- The Medium Term Conflict Detection and Resolution module takes into account own trajectory intent information and that of surrounding traffic, up to 15 – 20 minutes (up to the time that it is possible to obtain reliable information) and area information.
    - Traffic Conflict Resolution uses priority rules to determine which aircraft has the right of way and which aircraft has to manoeuvre.
    - The aircraft which has to manoeuvre is required to do so, as stated in the AFR Rules, so that the conflict resolution is not delayed up until the point the conflict has to be resolved by both aircraft.
    - Resolutions will be displayed in the form of a modified route which can be implemented automatically or manually through the Flight Management System.
    - The flight crew should be able to consider the appropriate conflict resolution manoeuvre, evaluate several options, and execute any given manoeuvre, with the only constraints being:
        - The manoeuvre has to solve all conflicts.
        - The manoeuvre shall not create new conflicts and be conflict free up to a TBD time[25] (e.g.,10min) beyond the medium term look ahead time.
    - Medium term CR will, under normal circumstances represent the most cost-effective traffic separation assurance option, since comparatively small changes in the trajectory will be sufficient to ensure aircraft separation.
    - The resolution algorithms will have to ensure that at no time during the flight, the aircraft trajectory will place the aircraft in a 2 minute state vector conflict (see Figure 8-6).

[25] To be investigated by future research.

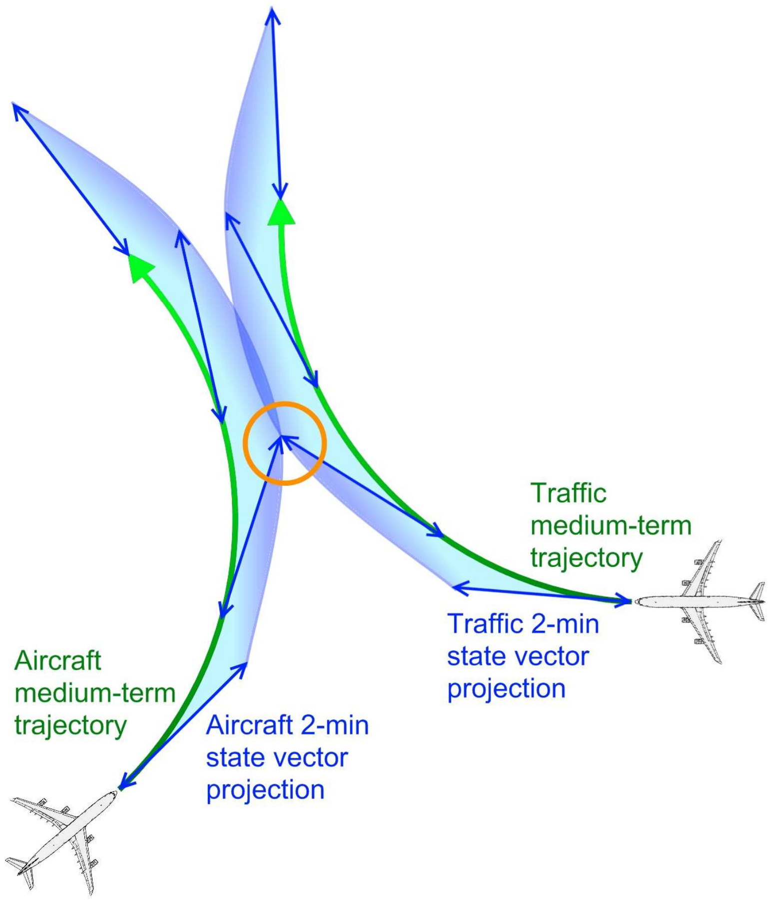

Figure 8-6 Cross-checking of state vector conflicts along the intent track. If the 2 min state vector predicted distance is less than the separation minimum (i.e. 3 Nm / 900 ft.) a conflict is detected. In this example the predicted lateral distance is zero Nm; as a result a conflict is detected.

8.6.3 Short Term Conflict Detection and Resolution (STCD&R)

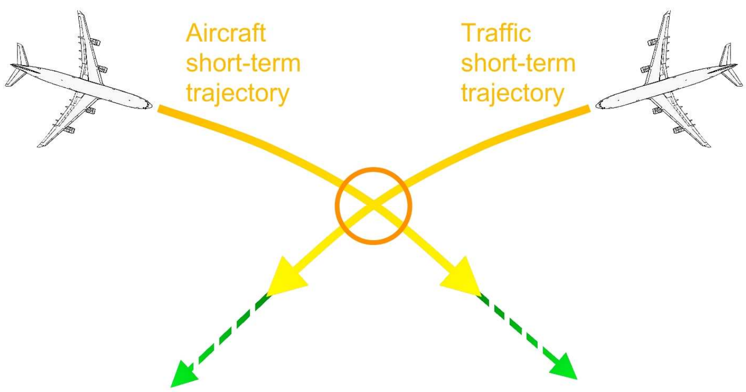

Figure 8-7 Short Term Conflict

- The Short Term Conflict Detection and Resolution module considers the best traffic information available up to the 3 to 5 minutes range, as well as area information. The traffic information may include the first level of intent (i.e., turn point or level-off altitude within 3 to 5 minutes). It is assumed that under normal operations the ownship aircraft will always be able to consider at least its own first level of intent.

- ○ Target State information, which is providing information on the horizontal and vertical targets (heading, speed and altitude) for the active flight segment, can be used as first level of intent.
- ○ The traffic state vector extrapolation is considered to be representative up to 5 minutes ahead.
- ○ Short Term CR will enable a quick execution of the conflict resolution; this will involve:
  - Fast automated assessment and calculations
  - Presentation of simple manoeuvre options to the flight crew
  - Primary focus will be on CR execution instead of trajectory management
- ○ Implicitly coordinated Short Term traffic CR requires that all aircraft use compatible resolution algorithms with a cooperative set of resolution manoeuvres. As the coordination among these manoeuvres will be implicit, there will be no direct communication between aircraft for manoeuvre coordination.
- ○ Short Term traffic CR algorithms will have to be able to resolve conflicts which involve several other aircraft (‘1 on N’ capability), and not create new conflicts.
- ○ When using trajectory change information the algorithms will have to ensure that at no time during the flight, the aircraft will be placed in a 2 minutes state vector conflict.

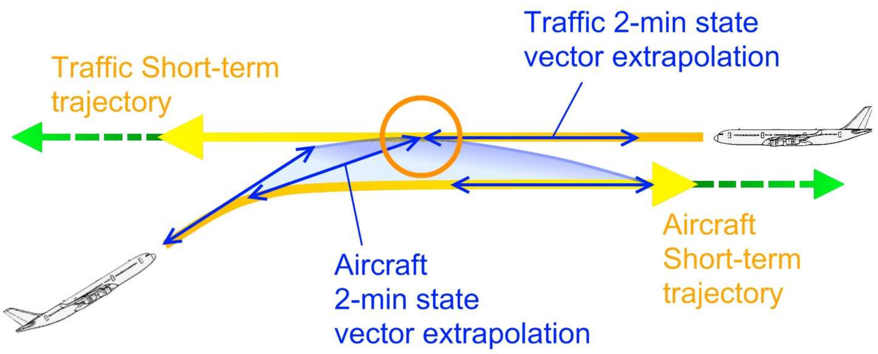

Figure 8-8 Two-minutes short term state vector conflict (level-off attitude example) If the 2 min state vector predicted distance is less than the separation minimum (i.e. 3 Nm / 900 ft.) a conflict is detected. In this example the predicted vertical distance is zero feet; as a result a conflict is detected.

8.7 Airborne Collision Avoidance System (ACAS)

- The A3 ConOps to be studied within iFly adopts current ACAS in the form of TCAS-II
- Beyond the iFly project it may be a valuable option to study the mitigation of possibly simultaneous and conflicting resolution advisories by ASAS and ACAS.

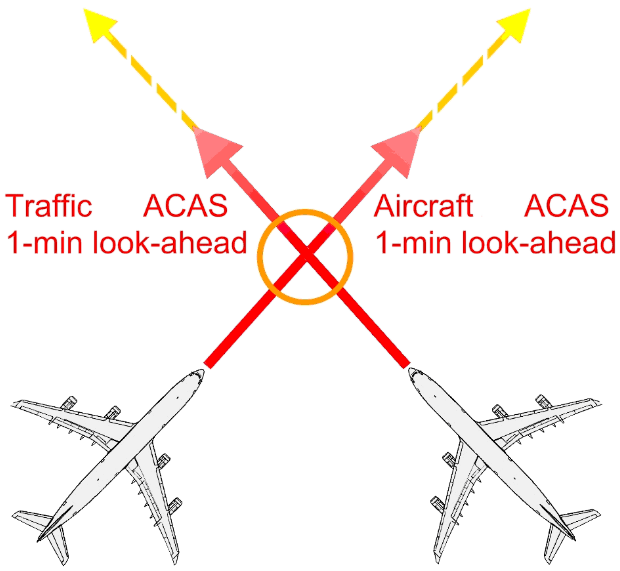

Figure 8-9 ACAS Conflict Detection works without intent and therefore may differ from ASAS conflict detection

8.8 Priority rules

- Priority rules only apply to Medium Term Conflict Resolution.
- In accordance with the autonomous flight rules, aircraft with lower priority have to manouevres to prevent the conflict from becoming a short term conflict, which would then have to be resolved cooperatively.
- A TBD set of rules, which will be identical to all aircraft, will determine the priority level of each aircraft. This priority level (or status) will be broadcasted so that it can be used by other aircraft. Considerations that have to be taken into account that determine the priority level:
    1. CTA requirements
    2. Manoeuvrability
    3. Mission Statement
- In case of identical priority levels, an arbitrary procedure (based in the aircraft call signs for example) will be used to ensure that priority is always unambiguous.

8.8.1 CTA requirements considerations

- As aircraft get closer to the TMA arriving point (Metering Fix), the Arrival Manager (AMAN) or the controlling entity of that airspace will/can issue an updated CTA with a reduced window size. As a result the onboard priority level will increase accordingly. In other words, when aircraft get a tighter constraint they also have a higher priority. The priority level is no indication of position in the arrival sequence but is only used for MediumTerm conflict resolution.

- Once an aircraft has a fixed CTA or is actively spacing, the priority assigned to that aircraft will be the highest under normal operations. However, this does not relieve the aircraft from the self-separation resposibilities required in SSA.

Normal Operations Priority Levels – CTA-related	
Priority level	**Aircraft status**
X	Normal priority level according to TBD priority rules
X+1	Smaller CTA time window than the other aircraft
X+2	Fixed CTA assigned or actively spacing aircraft

8.8.2 Manoeuvrability considerations

- The aircraft manoeuvrability classification, concerning:
    - Speed envelope
    - Turning radius
    - Climb rate

  will be considered in the priority level determination.

8.8.3 Mission statement categories for priority determination

- The aircraft mission will be reflected in its priority level. The following table summarizes some of the categories considered for priority determination:

	Category	Circumstances for Selection
EMERGENCY	Emergency	When an aircraft is in an emergency condition
NON-NORMAL	Non-own surveillance capable	Unable to broadcast its state and/or intent, its position only detected through primary radar
	Non-self separation capable	Aircraft can perform all its normal tasks, except self separation
NORMAL	Ambulance flight	When a flight is operating as an air ambulance and the patient is in a life threatening condition, or requires stable flight operations.
	Military aircraft in a national defence mission	Applies to those military aircraft which are performing surveillance broadcasting (does not apply to fighters in an interception mission, spy aircraft or other which do not broadcast their state and intent)
	Military ordnance transport	When a military aircraft is carrying sensitive ordnance (weapons, explosives, or other harmful materials) in a transport mission
	Special Transport	Civil aircraft carrying dangerous or sensitive goods
	Scene of Search	When an aircraft is operating at the scene of a search area or is operating as a scene of search co-ordinator. If an aircraft is en-route to or from a scene of search, it should be treated as a normal aircraft
	Prioritized VIP aircraft	High level government officials (not Head-of-states) which have been given a higher level of priority
	Normal Aircraft	When non of the above is applicable

- Non-normal and emergency aircraft will broadcast higher priority levels than normal operating aircraft. The condition of the aircraft may have to be manually entered into the system as to update the priority level.

8.9 Transition Operations

- The A^3 ConOps does not consider transition operations in/out SSA, however a few outlines are given in order to provide a more complete vision of this Operational Concept.

- ANSPs managing TMAs are responsible for separation and flow management for aircraft inside their MA. The following relationship exists between the part of the aircraft's trajectories that takes place in SSA and the transition to MA:
    - ANSPs will issue arriving and exiting CTA restrictions in order to maintain safe and efficient operations inside the TMAs.
    - When required by circumstances, ANSPs will broadcast new CTAs for aircraft entering or exiting TMAs.

- Aircraft will leave the departure TMA in a position, time and course specified by their 4D take off and departure trajectory contract. The ANSP will have to ensure that the active RBT will be conflict free for a TBD timeframe (e.g., 10 min) when leaving the TMA.

- The aircraft will have to meet the arriving TMA CTA under the following conditions:
    - The aircraft has to be conflict free when entering TMA airspace.
    - The aircraft speed and course will conform to a 4D trajectory contract into TMA.
    - The aircraft needs to be able to anticipate any failure to meet the CTA requirement and inform the ANSP in advance, so that the CTA and entry requirements can be adjusted accordingly.

- CTAs will be produced by CDM (Collaborative Decision Making) between the Pre-Flight actors and ANSPs. The resulting exit/entry TMA organization (at the SFM level) should ensure, in principle:
    - Conflict-free normal operations (i.e. if aircraft do comply with CTAs, they will be conflict-free in the immediate vicinity of the High Density – TMA boundary).
    - The achievement of a safe, orderly and expeditious flow of traffic.
    - The goal is to avoid generation, at a managing level, of any 'a priori' conflicts.

- Controlled Times of Arrival are ***not*** exact times for arrival. Rather, they represent a time window whose margins are refined in the course of the flight:
    - Initially, the ANSP gives the aircraft a CDM-originated CTA, along with a time window, representing the original estimation for that particular aircraft arrival.
    - As the flight progresses, the time window is reduced, reflecting the aircraft actual manoeuvres; this process takes place without the need of a RBT modification (for example: an aircraft has had to solve several conflicts and thus its CTA-compliance is displaced towards a later time, but it is still inside the original CTA interval; a new and reduced interval is defined in order to allow the aircraft to still comply to CTA).

  - At the final stages of the aircraft's en-route phase of flight, a 'CTA lock-down' is issued in the form of a fixed CTA, along with an appropriate priority level increase for that aircraft; at this point the time for the aircraft arrival is fixed.

- The ANSP may issue spacing instructions (TTF and SI) to equipped aircraft in order to enable them to transition from a 4D operation to a Merging and Spacing (MS) operation. Aircraft that are actively spacing outside the TMA are still required to remain separated from all other aircraft. However, spacing aircraft will have priority over normal non-spacing or non CTA constrained aircraft.

8.10 Military operations

- The A^3 ConOps is primarily aimed at the operation of civil transport aircraft. However, aircraft performing military or national tasks can be accomodated in this concept.

- All military aircraft (fighters, transport, UAVs, etc) have to be properly equipped, capable of self separation and follow AFR rules to be able to enter and operate in SSA, just like all other aircraft.

- While it is outside the scope of this ConOps to assess all possible military operations, two cases are considered, in order to show the potential flexibility of the A^3 ConOps:
  - The interception of a civil aircraft by an air defense fighter.
  - The operations of a head-of-state aircraft.

8.10.1 Intercept missions

- The mission requirements of air defense fighter aircraft in an interception mission may be opposite from the main basic assumptions presented in this ConOps: while the goal for autonomous aircraft is to maintain separation, intercept missions require that fighter aircraft get close enough to the target aircraft without being detected.

- In order to avoid detection by the target, the intercepting aircraft may:
  - deactivate the Air-Air DL, while retaining 'IN' (receiving) functions operative, allowing it to achieve traffic SA through Air-Air DL and SWIM;
  - indicate to SWIM that own position updates will not be made available to other SWIM users.

- Due to the fact that intercepting aircraft cannot be detected by other aircraft, interceptors will have the sole resposibility to maintain separation with all other aircraft.

- The following picture (Figure 8-10) shows a schematic description of the interception mission communications/surveillance functions:

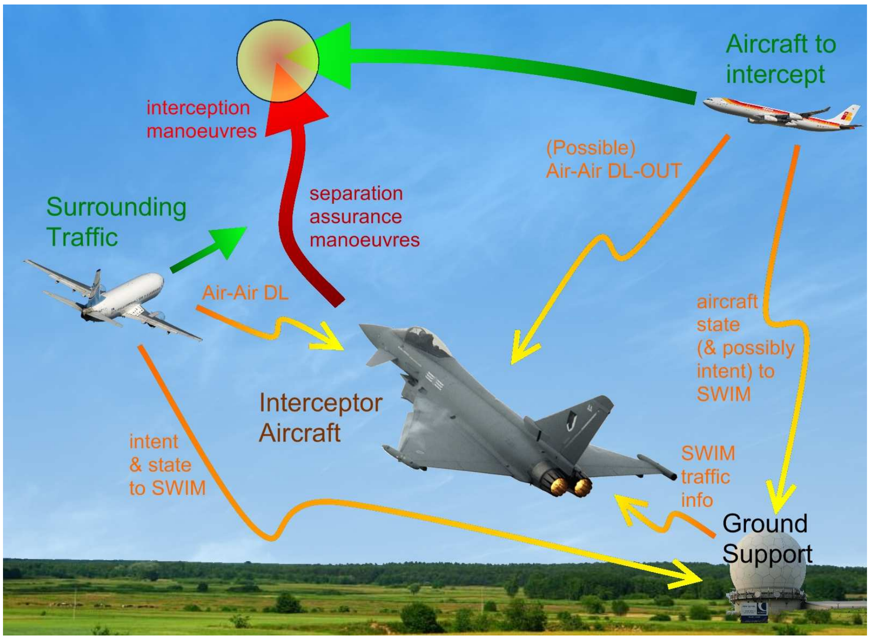

Figure 8-10 Military Interception Mission Communications and Operations Scheme

8.10.2 Head-of-state aircraft operations

- Head-of-State (HS) aircraft will require that other airspace users maintain a larger than normal separation distance. Furthermore, there may also be a requirement that other aircraft should be unaware of the presence of such a valued aircraft.

- HS aircraft may opt to use a common / generic call sign which will make the aircraft indistinguishable from other traffic aircraft.

- HS aircraft may also be using a higher separation class and/or priority value, which will force other aircraft to maintain a larger separation distance and require them to move first in case of conflict.

8.11 Non-normal and Emergency Operations

8.11.1 General considerations

- The terms ‘Non-normal operations’ and ‘Emergency Operations’ in the A^3 ConOps refer to:
    - ***Non-normal Operations:*** those operations that require a modification of normal operations, as they have been defined in the A^3 ConOps, but where the aircraft can still meet the required safety levels under the general assumptions made.
    - ***Emergency Operations:*** operations where safety levels for the aircraft cannot be maintained under the general assumptions made in the A^3 ConOps.

- In general, the following considerations apply for Non-normal and Emergency operations:
  - ***Concerning overall self separation capabilities:*** Aircraft that are aware of the fact that they are no longer capable to self-separate will be required to enter Managed Airspace as soon as they are able. Other aircraft will have to perform all separation requirements regarding that particular aircraft when it still is inside SSA. Non-normal aircraft may be required to transmit their operational performance level, which is an indication of their self separating capabilities. See table in section 9.2.4.
  - ***Concerning medium term conflict management:*** When an aircraft is in a non-normal or emergency situation the crew or automation will update the condition level of the aircraft. The condition in which the aircraft operates will affect the priority level that will be broadcasted. Aircraft in a non-normal or emergency situation will broadcast a higher priority level.
  - ***Concerning short term conflict management:*** cooperative resolution manoeuvres in State Based CR will ensure that the conflict will be resolved even if the participating Non-normal aircraft is unable to manoeuvre.
  - ***Concerning surveillance capabilities:***
    - Loss of Air-Air DL will have to be indicated to the SWIM network by any means possible. Ground applications will continue to track the aircraft through position reports and/or radar returns. Other aircraft will continue to receive surveillance updates for this aircraft through the SWIM network as long as the aircraft is in SSA.
    - When an aircraft trajectory information is not available through any of the normal means, SWIM might provide dynamic RAA around a non-self separating aircraft. Affected traffic will avoid that RAA as an area conflict.

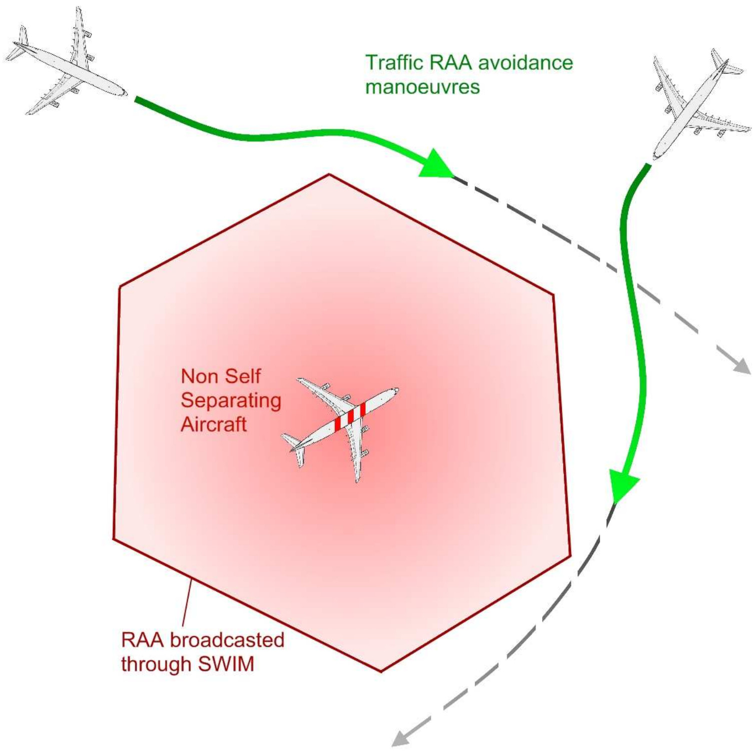

Figure 8-11 Dynamic RAA around a non-self separating aircraft

- *(cont.)*
    - ***Concerning Navigation Performances:*** any aircraft that is not able to conform to its broadcasted intent, will have to indicate this to the SWIM network The procedure may require the aircraft to broadcast a different SM class in order to maintain the safety level of the operations.

8.11.2 Non-normal Operations

- The degradation in the specified levels of performance for non-normal operations, will require modifications of the operational procedures to maintain the required safety levels under the A^3 ConOps.

- Non-normal ATM performances can be classified as a reduction in:
    - Navigation performances
    - Communication/Surveillance performances
    - Trajectory and conflict management performances

8.11.2.1 Navigation performances

- The proposed ATM system will depend on the aircraft's ability to adhere to a required accuracy of their broadcasted trajectory intent.

- Required Navigation Performance Capability (RNPC) is defined *as a parameter describing lateral deviations from assigned or selected track as well as along track position fixing accuracy on the basis of an appropriate containment level* [26]. RNP types specify the minimum navigation performance accuracy required in an airspace.

- If an aircraft is not able to conform to its broadcasted trajectory (a certain RNP being considered), it will broadcast its 'non-conformance' status – when there is a non-conformance with the RBT – and/or a message of 'Aircraft Navigation Equipment Status - diminished', along with the reduced RNP type, as stated in the Information Flows table of section 9.2.4.

- The Separation Minima class regarding the non-conforming aircraft may have to be adjusted to reflect diminished navigation performance. The SM class of the aircraft will be broadcasted and made available to the SWIM network. The flight crew of other aircraft will be able to distinguish the different SM class, but otherwise will proceed as normal.

8.11.2.2 Communication/Surveillance performances

- ***A Communication/Surveillance performance drop may impact either:***
    - An aircraft's ability to determine its position and trajectory (Surveillance).
    - An aircraft's ability to communicate its position and trajectory (Communication).

[26] As defined by the FANS Committee, ICAO Doc 9613-AN/937 Manual on Required Navigation Performance.

- ***Surveillance:*** if an aircraft is not able to accurately determine its position and trajectory, then this information will have to be made available to all surrounding traffic. SWIM may continue to provide position updates for this non-normal aircraft correlating available data with other secondary surveillance means (e.g. primary radar). The non-normal aircraft may still be able to provide reduced self separation capabilities. As with the case of reduced navigation performance, the non-normal aircraft SM class may have to be increased to reflect the reduced positioning accuracy.

- **Communications:**
    - Loss of Air-Air DL communications will be compensated by SWIM. However, the SWIM update rate and accuracy might reduce ASAS performances. The non-normal aircraft will communicate its operational performance level and its SM will be reclassified to reflect the situation.
    - Loss of SWIM communication will merely cause a reduction in ASAS efficiency and trajectory management capability, but will not result in greatly diminished ASAS performance. Aircraft’s SM may not have to be reclassified.
    - Simultaneous Air-Air DL and SWIM loss will effectively make the avionics of that aircraft ‘blind’, and therefore incapable of self separating. The aircraft is required to reach MA as soon as able, and use all means available to communicate its position to other aircraft. The tasks of maintaining separation from that aircraft will fall upon nearby aircraft’s flight crews.

8.11.2.3 Trajectory and conflict management performances

- If an aircraft has only a partial loss of its CD&R performances, and it is still capable of performing self separation, given that the situation:
    - Does not require too much effort from the flight crew, and
    - Does not represent problems that are too complex for a reduced capabilities on-board system,

  the aircraft will continue to operate under the appropriate priority levels and SM class.

8.11.3 Emergency Operations

- An emergency occurs when an unforeseen event creates a hazard to the passengers, the crew, or the aircraft, which requires immediate action. In the context of the A^3 ConOps, an emergency is considered to be any situation in which the safety levels for the aircraft cannot be maintained under the assumptions made.

- ***Main rule:*** Emergency aircraft will obtain the highest priority level and will be required to exit SSA and reach Managed Airspace as soon as they are able.

- When an aircraft crew belives it´s aircraft is in an emergency situation, then that aircrew will be able to declare an emergency through all communication means available:
    - Through the aircraft emergency frequency (International Air Distress (121.5 MHz) for civil aircraft, Military Air Distress (243.0 MHz) for military aircraft).

  - Through the enabled voice communication frequency in that particular sector.
  - Through Air-Air DL and SWIM (emergency/priority status message).
  - Adjusting the SSR transponder to reply on Mode 3/A Code 7700.

- The aircraft emergency status will also be made known to all actors through SWIM.

- The emergency aircraft will in collaboration with the governing ANSP be able to choose a preferred route into Managed Airspace.

- Separation responsibility from aircraft which have declared an emergency will fall upon nearby traffic.

- The SM classification used for the emergency aircraft will take into account:
  - Possible deviations from the aircraft declared trajectory.
  - A possible surveillance capabilities degradation.
  - The aircraft actually not providing any surveillance information, which will mean having to rely upon SWIM data, which will be less accurate and with a lower update rate.
  - The hazard that an emergency aircraft presents to nearby traffic, by itself.

- The procedures (which will involve ATC) concerning the transition of an emergency aircraft from SSA to MA are not considered.

- In order to prioritize the entrance of the emergency aircraft into MA, the governing ANSP may have to issue a new set of CTAs to all other aircraft. CTA changes to other aircraft, as a result of an emergency, will not be subjected to negotiation between the other aircraft and the ANSPs.

9 A³ Systems

9.1 Communications

- Aircraft data links may use various networking protocols. Currently the most commonly used protocol is ACARS (Aircraft Communication Addressing and Reporting System), however, in a near future there are plans to replace the outdated ACARS technology with ATN/CLNP (Air Traffic Network, Connectionless Network Protocol). In a distant future, network communication will possibly change to IP (Internet Protocol), which is nowadays the most widespread network protocol.

- The communications will be utilized for
    - Requests for flight/trajectory changes.
    - Data exchange for distributed decision making.
    - Digital audio/video transmissions.
    - Shared data exchange with SWIM.

- It will enable data transmission, particularly:
    - Point to point data transfer (air to ground, ground to air, air to air).
    - Broadcast data transfer (air to air and air to ground).

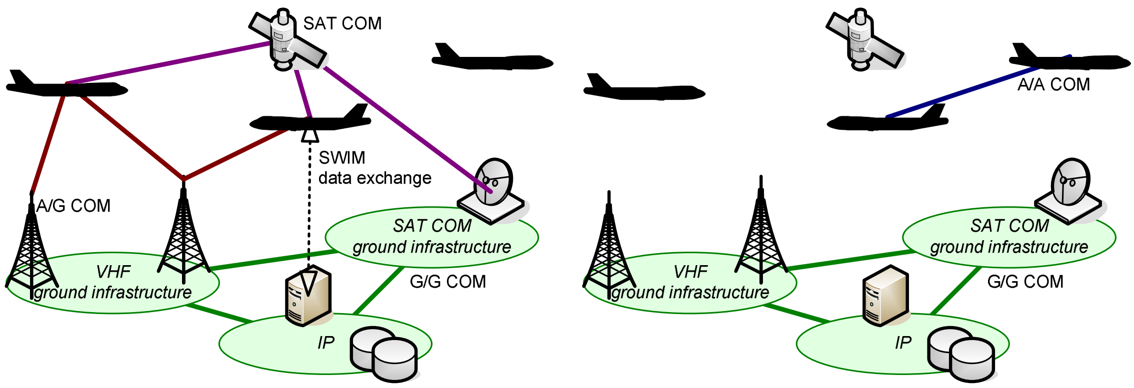

Figure 9-1 Overview of the communication data links considered in A³

- For different transmitted information a different digital data encoding may be used (as mentioned by SESAR WP8). The task of data encoding is to provide data safety, security (confidentiality, integrity, non-repudiation) and increase attack resilience.

- The data encoding and transport issues cannot be delegated to ground; both communicating peers must collaborate on this.

- There are many hazards related to communication. This is especially important when Commercial Off-The-Shelf (COTS) technologies like IP will be used.
    - Communications must be resilient to attacks on confidentiality, availability, integrity, or non-repudiation.
    - The system must be resilient to delays or service interruptions caused by network congestion or transmission errors on physical layer.

9.2 *Automated Ground Surveillance Support*

- To cope with possible limitations of the direct air-air communication (at least for currently studied data links) and to provide a consistent availability of the information for the individual awareness zones, different (ground involving) information gathering mechanisms, shown in Figure 9-2 are foreseen:
    - For MTAZ a fully automated information sharing mechanism with the ground surveillance tools is considered:
        - A **Traffic Proximity Detection** function will, according to the definition of the MTAZ, provide each aircraft a list of all aircraft that are of influence to the operation of that aircraft.
        - Based on this list, onboard automation can query the SWIM network for missing State and Intent information (not obtained through direct Air-Air Data Link).
    - For LTAZ the information about areas-to-avoid are uploaded to aircraft. These areas include complex areas determined by a ground-based automated **Complexity Predictor**.

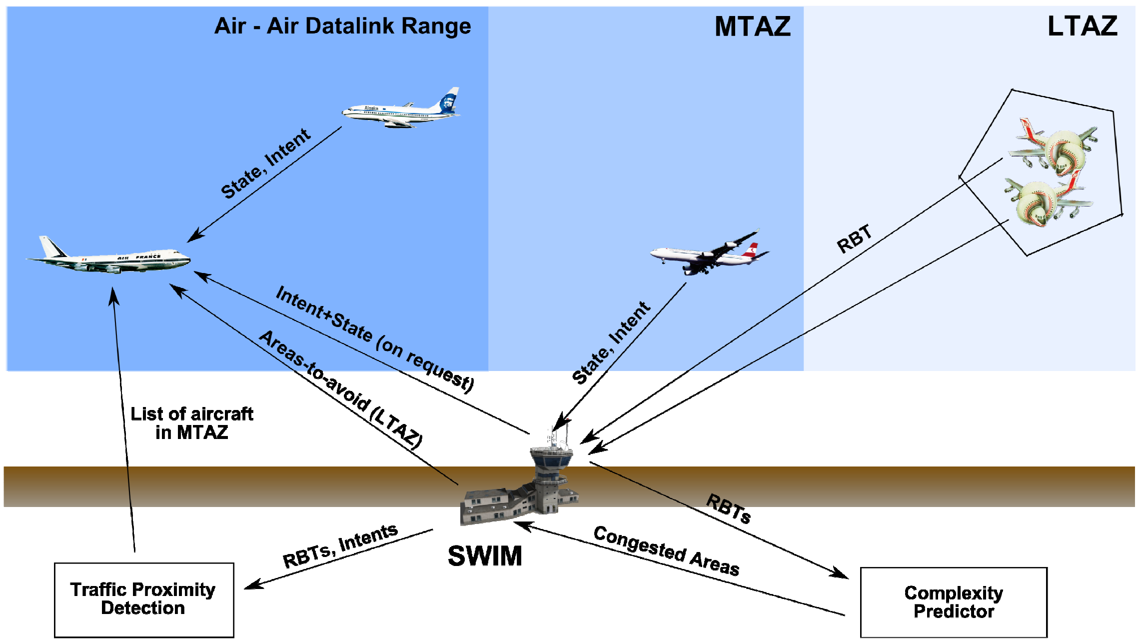

Figure 9-2 Surveillance information communication structure

9.2.1 Information Sharing System

- The System Wide Information Management network (SWIM) will provide different means to obtain the data:
    - Pull-model: Some data will be available “upon request” (query) , e.g., State and Intent data of aircraft outside the Air-Air Datalink range.
    - Push-model: Some data will be periodically sent to the aircraft, e.g.,i.e., Areas to avoid, weather information. Depending on data importance, this may or may not be based on a subscription (that will indicate the refresh frequency).

- On the airborne side, the information processing unit is responsible for the communication with SWIM.

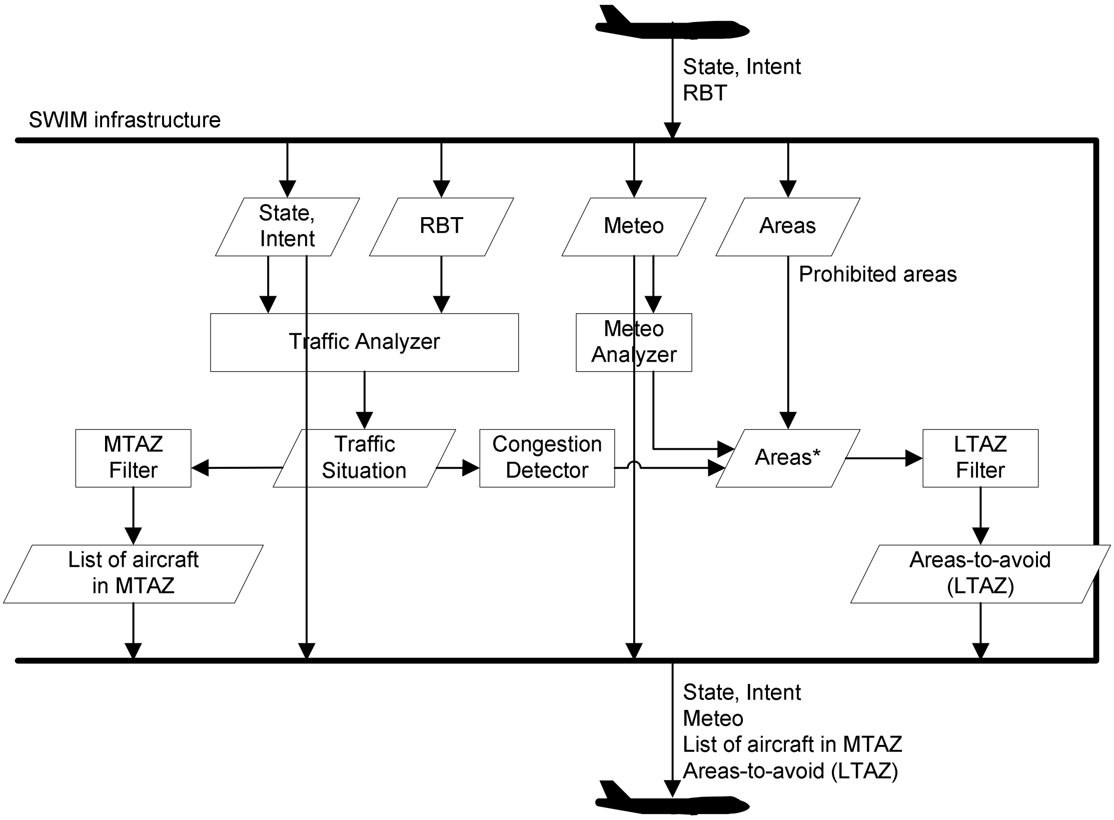

Figure 9-3 Overview of SWIM functionalities anticipated in A^3

9.2.2 Traffic Proximity Detection

- This tool will regularly detect all aircraft crossing the MTAZ of each aircraft within the medium term timeframe. The corresponding list is sent to each aircraft and used by its on-board systems to request missing (not obtained though direct air-air communication) data of other aircraft from SWIM.

9.2.3 Complexity Predictor

- This automated tool will use the RBTs (stored in SWIM) to evaluate a suitable traffic complexity metric across the airspace. Based on the predefined threshold(s) (there may be more levels of complexity) complex areas are detected and together with other areas-to-avoid provided to aircraft. This approach may potentially also be used for indirect strategic flow management by using a selective sets of areas-to-avoid.

9.2.4 Information Communication Structure

- In the ensuing Information Flows table, an account of the possible information exchanges between all actors is provided. Each column provides the following information:

- Information flow: the subject of the information exchange.
- Message: the contents on the subject of the information exchange.
- Sender: which A^3 ConOps actor is emitting the message.
- Means: which communication channel (Air-Air DL, SWIM or both) is used.
- Destination: which A^3 ConOps actors are receiving the message.
- Acknowledgement: which receiving actors have to answer acknowledging the message was received.
- Description: a brief text outlining the meaning of each message.

Information Flow	Message	Sender	Means	Destination	Acknowledgement	Description
SBT	Planned	ANSP	SWIM	SBT Aircraft FOCs	SBT Aircraft FOCs	Pre-flight Trajectory Information; analogous to current Flight Plan.
RBT	Initial	Aircraft	SWIM	Ground Support FOCs ANSPs	None	RBT is the flight trajectory information while the aircraft is flying; initial RBT activation is made just before take off (procedures fall outside A3 ConOps).
	Updates	Aircraft	SWIM	Ground Support FOCs ANSP	None	Manoeuvres made by the aircraft, CTA actualizations and trajectory changes in-flight are reflected in RBT updates.
MTAZ Proximity Traffic	Timely Updates	Ground based application	SWIM	Aircraft	Aircraft	Aircraft are notified of all traffic present in their MTAZ.
Aircraft STATE	State Info	Aircraft	SWIM, Air-Air DL	MTAZ Aircraft	None	The aircraft State info comprises the position, velocity, course & altitude information, along with an aircraft ID, separation class and a priority tag.
Aircraft INTENT	Intent Info	Aircraft	SWIM, Air-Air DL	MTAZ Aircraft	None	The aircraft Intent info consists of Trajectory Change Points (TCPs) and conformance monitoring data.
CTA	Initial	ANSP	SWIM	Aircraft own FOC Aircraft	Aircraft	Initially, the aircraft will be notified of its CTA by the ANSP, along with an uncertainty time window which will depend on the duration and characteristics of the flight.
	Updates	ANSP	SWIM	Aircraft own FOC Aircraft	Aircraft	The CTA will be refined along the flight, depending on the conditions the aircraft encounters. This includes both CTA time window reducing and (only if necessary) CTA relocation beyond the time window.
RTA	Final	ANSP	SWIM	Aircraft own FOC Aircraft	Aircraft	As the aircraft gets close to the arriving TMA, it will be provided with a fixed CTA. This will result in a higher priority level in the arriving phase of its flight.
Very Short Term Traffic Alert (ACAS system)	State - Very Short Term	Aircraft	Secondary Air-Air Comm.	Conflicted Aircraft	Conflicted Aircraft	Conflict Resolution at very short term (including collision avoidance) is explicitly coordinated.
Aircraft Priority Status	Normal	Aircraft	SWIM, Air-Air DL	MTAZ Aircraft	None	Medium Term Conflict Resolution is priority-based; aircraft will communicate their priority level through their State Vector message.

Information Flow	Message	Sender	Means	Destination	Acknowledgement	Description
	Non-normal	Aircraft	SWIM, Air-Air DL	MTAZ Aircraft	None	In the case of a non-normal situation, the aircraft priority level is increased, separation class is changed and a 'non-normal' indication will be sent as well.
Congested/Complex Areas Information	Area Info	Ground based application	SWIM	All Aircraft	None	Congested and/or complex areas are used in LTAZ where they are determined by a ground-based application.
RBT Conformance	Adherence	Aircraft	SWIM	Ground Support	None	Aircraft will send a 'RBT conformance' status message at certain time intervals.
				Own FOC		
	Alert	Aircraft	SWIM	Ground Support	None	If an aircraft detects a loss of conformance with its RBT, it sends an alert message and its status changes to 'RBT non-conformance'.
				Own FOC		
Aircraft SM Class	SM class I	Aircraft	SWIM, Air-Air DL	MTAZ Aircraft	None	Aircraft in normal condition will have a Class I SM; aircraft in non-normal conditions will have a different SM Class which results in greater SM.
				Own FOC		
	Other SM class	Aircraft	SWIM, Air-Air DL	MTAZ Aircraft	None	
				Own FOC		
Aircraft Navigation Equipment Status	Nominal	Aircraft	SWIM, Air-Air DL	MTAZ Aircraft	None	Aircraft will send a 'Nav systems nominal' status message at certain time intervals, along with their RNP level.
	Diminished	Aircraft	SWIM, Air-Air DL	MTAZ Aircraft	MTAZ Aircraft	If an aircraft is not able to comply with its nominal RNP, it will send a 'Nav systems diminished', and a RNP level if possible.
				Own FOC		
	Failure	Aircraft	SWIM, Air-Air DL	MTAZ Aircraft	MTAZ Aircraft	A 'Nav systems Failure' message implies an Emergency Situation. See Emergency Operations.
				Own FOC	Own FOC	
				ANSP		
Aircraft ASAS Equipment Status	Nominal	Aircraft	SWIM, Air-Air DL	MTAZ Aircraft	None	Aircraft will send an 'ASAS systems nominal' status message at certain time intervals, along with their ASAS performance level.
	Diminished	Aircraft	SWIM, Air-Air DL	MTAZ Aircraft	MTAZ Aircraft	If an aircraft has diminished ASAS capabilities, it will send an 'ASAS systems diminished', and an ASAS performance level if possible.
				Own FOC		
	Failure	Aircraft	SWIM, Air-Air DL	MTAZ Aircraft	MTAZ Aircraft	An 'ASAS systems Failure' message implies an Emergency Situation. See Emergency Operations.
				Own FOC	Own FOC	
				ANSP		
Aircraft System Status	Diminished	Aircraft	SWIM, Air-Air DL	MTAZ Aircraft	MTAZ Aircraft	This category covers other aircraft systems performance losses that may affect the aircraft ability to maintain self separation. A 'Diminished' status implies the loss of certain capabilities (e.g. Manoeuvrability).
				Own FOC	Own FOC	
				ANSP	ANSP	
	Failure	Aircraft	SWIM, Air-Air DL	MTAZ Aircraft	MTAZ Aircraft	A 'Systems Failure' Message implies an Emergency Situation. See emergency Operations.
				Own FOC	Own FOC	
				ANSP	ANSP	

Information Flow	Message	Sender	Means	Destination	Acknowledgement	Description
Weather	Meteo Data	Weather Server	SWIM	All Aircraft FOCs ANSP	None	Air data forecasts will be broadcasted to all aircraft.
	Restrictions	Weather Server	SWIM	All Aircraft FOCs ANSP	None	A 'Restrictions' message may provide areas to avoid, maximum speed indications, or other operational constraints.
	Warning	Weather Server	SWIM	All Aircraft FOCs ANSP	None	A 'Warning' message is of the same format as a 'restrictions' message, but is used for severe conditions that may threaten the safety of the flights.
Airspace	Restriction	ANSP	SWIM	All Aircraft FOCs	FOCs	ANSP will issue Airspace Restrictions in the form of Areas to avoid.
	Restoration	ANSP	SWIM	All Aircraft FOCs	FOCs	This message implies the lifting of a given airspace restriction.

9.3 Cockpit/airborne System

- Due to the fact that within autonomous operations more tasks and responsibilities will fall on the operating crews, the whole A^3 airborne system is designed as a pilot's decision supporting tool.

- The process described above assumes three new airborne applications & functionalities:
    - **Information Processing Unit** – that gathers information from external sources and categorises these into appropriate data sets.
    - **Airborne Separation Assistance System (ASAS)** – that assists in both strategic conflict management as well as separation provision, which will result in tactical changes of the RBT.
    - **Trajectory Management** – that increases the performance of the flight through strategic RBT changes.

- A possible Airborne System Functional Architecture is shown in Figure 9-4:

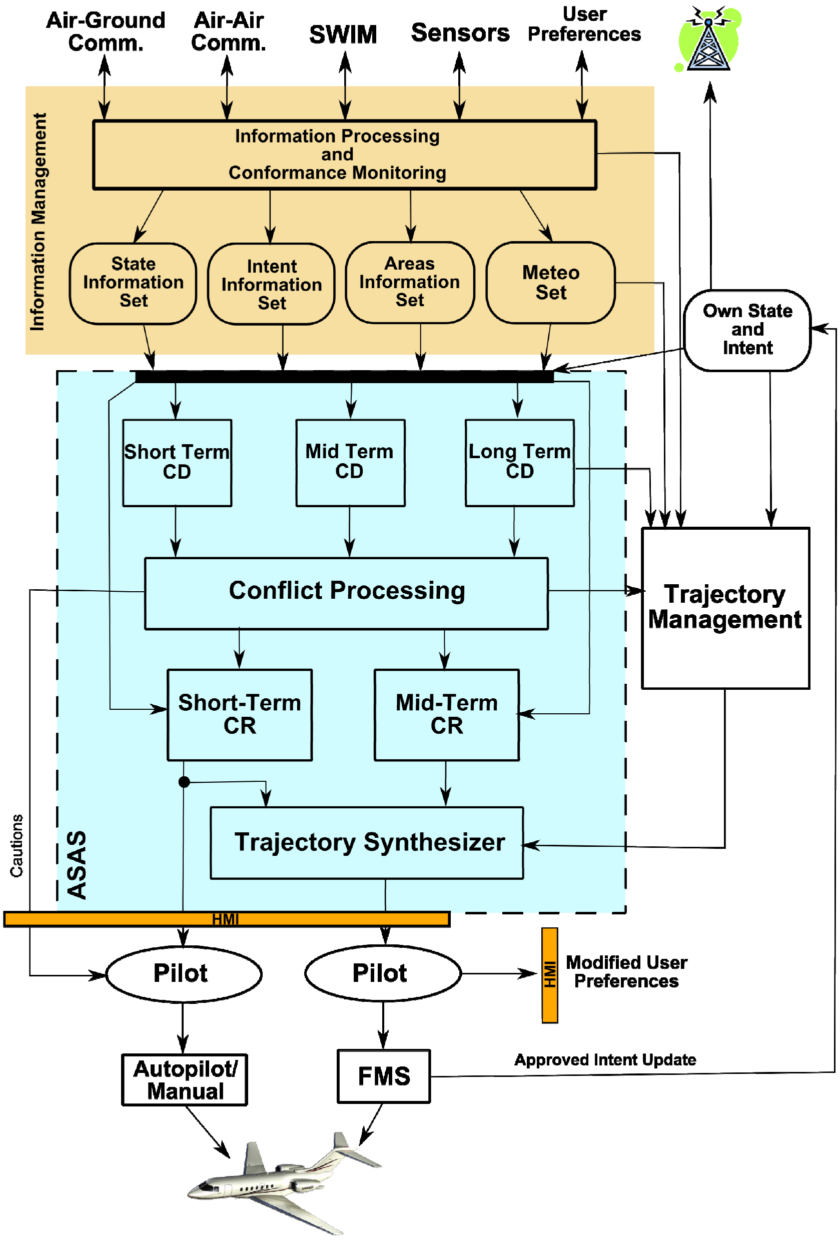

Figure 9-4 Airborne System functional architecture

9.3.1 Information Processing Unit

- The information management system will receive surveillance data from airborne and ground based surveillance functions, particularly:
    - Information (state, intent) coming through direct air-air communication links (e.g., ADS-B/C).
    - Information (state, intent, areas, weather) coming from direct air-ground communication links (e.g., TIS-B/C).
    - Information coming from SWIM information services.
    - Information from on-board sensors, namely weather radar or EGPWS.

- The system will provide the highest possible precision. It will detect missing or obsolete information. If possible, the system may:
  - Approximate missing information (e.g., using Kalman filter).
  - Query the information from SWIM or neighbouring aircraft.
  - Compose the data from multiple sources (data fusion). For example, the system will use the state information (having higher update rate) for intent conformance monitoring. This information will supplement the conformance information within the intent message.

- The information accuracy may decrease due to communication errors. The system will therefore indicate a confidence level for the supplied information. When errors occur, the system will supply degraded data and indicate lower confidence.

- The main goal of the information processing unit is to keep updated the four on-board information sets:
  1. **State traffic information set –** contains all updated state information (position & velocity vectors, priority level and separation class) coming mainly from direct air-air communication (SWIM can also provide State information if needed).
  2. **Intent traffic information set –** contains updated 4D trajectories (state and intent trajectories) of all aircraft crossing the MTAZ within the medium term timeframe. The trajectories are based on the data obtained via direct Air-Air Data Link channels or automatically queried from SWIM.
  3. **Areas information set –** contains updated information about hazardous (weather, congested…) and restricted areas within the LTAZ. Data will be provided by SWIM (update frequency in order of tens of minutes) together with on-board systems (e.g. weather radar, EGPWS). Complex areas outside of MTAZ are determined by a ground-based application (within the MTAZ, traffic complexity is determined by an on-board system).
  4. **Meteo set –** contains updated information about measured air data and about forecasted wind and temperature conditions for the remaining part of the flight. This data is obtained through on-board sensors and/or through SWIM.

- The information processing unit will be based on complex algorithms combining all available data about each aircraft to determine the most reliable and accurate information for individual information sets.

9.3.2 Airborne Separation Assistance System (ASAS)

- The A^3 airborne separation management process consists of the following main phases:
  - Conflict Detection
  - Conflict Processing
  - Conflict Resolution
  - Business Trajectory Synthesis
  - Execution

- While the Conflict Detection (CD) and Conflict Resolution (CR) phases are split to several parallel modules, the Conflict Processing and Trajectory Synthesis are integrative phases processing information from all related modules.

- The Conflict Detection functionality is divided according to the type of trajectory information. On the contrary, Conflict Resolution functions are split based on the urgency of conflicts. In previous research, these two splitting are typically aligned to each other (state-based conflicts are always solved by a short-term CR, etc.). While A^3 allows this kind of logic, it does not restrict algorithm developers to it. The only connection between the CD and CR modules is that CR algorithms must be able to process the trajectory information used to detect a conflict to solve. Additional requirements may arise from the necessity to process trajectory information for prevention of secondary conflicts. In this context, A^3 ConOps allows that the boundary between Medium Term and Short Term CR is designed independently of the CD process.

9.3.2.1 Conflict Detection

- Conflict detection process is split into three independent modules which differ in the use of the individual information sets. This allows a development of targeted and optimized algorithms for specific tasks:
    1. **Short Term CD** uses information from the State Information set together with own state and first level of Intent (i.e., turn point or level-off altitude within 3 to 5 minutes) to perform CD for the short term timeframe.
    2. **Medium Term CD** uses information from Intent Information Set together with own state and intent and performs intent-based CD for medium term timeframe (including short term). In the case of missing intent information, best available intent is used, including the use of an extrapolation of the state information to build a “provisory intent” with a limited timeframe (e.g., 5-6 minutes). The Intent CD function will also detect areas of high complexity (assessed by an appropriate complexity metric) and/or monitor the own aircraft manoeuvring flexibility.
    3. **Long Term Areas CD** uses information from the Areas Information Set together with own state and intent and checks for possible penetration of undesirable areas within the long term timeframe (across all three considered timeframes).

- If a conflict is detected by any of the conflict detection modules, it passes through to the Conflict Processing module, which will process the information and send it to the resolution modules and via the HMI to the flight crew.

9.3.2.2 Conflict Processing

- Within the Conflict Processing module all conflicts issued by CD modules are processed and the suitable action is determined. If the situation requires a modification of own trajectory, one of the **corrective actions** is selected:
    - **Short Term CR –** is selected when an immediate call for action is required (i.e. within seconds).
    - **Medium Term CR –** is selected when a timely call for action is required (i.e. within minutes).
    - In case of detected conflicts outside the medium term timeframe the **Trajectory Management** (not ASAS function) is activated.

- Situations which would only become dangerous if failures occur (e.g., FMS failure to follow lateral path), also know as blunder conflicts, one or both of the following actions will be taken:
    - The situation is registered and further analyzed during following iterations.
    - A **caution** indication is provided through the HMI to make the crew aware of the situation.

- It is anticipated that the processing logic may be complex and be subject of extensive research and validation. It has to be developed taking into account the specifications of available algorithms.

- If applicable, priority rules will be evaluated and taken into account in the selected action.

- When a conflict is to be presented to the flight crew, it must be given in a timely and effective manner. The amount and content of information which is needed by the flight crew to enter the decision making process regarding conflict resolution is subject to investigation.

9.3.2.3 Conflict Resolution

- Depending on the urgency of the conflicting situation there are two different CR modules. They differ in the time that is required for action and in the form and execution of the CR manoeuvre(s):
    - **Short Term CR** addresses conflicts with a short time to Loss of Separation (LoS) – (up to ~3-5 min). In this context immediate action is required (research parameter, typically about 30 s). The module generates only an isolated CR manoeuvre, not a consistent RBT update (this is resolved subsequently by Trajectory Synthesizer). The pilot will decide to execute the manoeuvre manually or via the mode control panel of the autopilot.
    - **Medium Term CR** addresses conflicts with a longer time to Loss of Separation (LoS) – (up to ~10-20min). In this context timely action is required (research parameter, typically 1-2 minutes). Within Medium Term CR manoeuvres are generated in the form of a consistent RBT updates that can be provided to the FMS and executed. In this way strategic constraints are taken into account as well as the manoeuvre optimization.

- The CR modules receive all relevant information about the triggering conflict. In addition they may access all information in the individual information sets, based on the algorithms needs.

1. *Short Term CR algorithm characteristics:*

- CR algorithm will be capable of resolving conflicts with multiple aircraft (1 on N) at once. Otherwise, the impact of a lack of this functionality on the overall system performance and safety must be analyzed.

- It is assumed in the A^3 ConOps that the CR algorithms will ensure an implicit coordination of the manoeuvres between the conflicting aircraft. An alternative approach is possible but in this case its impact on the operations and the overall A^3 performance and safety must be analyzed and described in detail.

- Both state and intent information will be used in the CR algorithm.

- The CR will not generate secondary conflicts within the specified look-ahead time (e.g., short-term timeframe). Alternatively, a Conflict Prevention (CP) system (not included in our scheme) to avoid new short-term conflicts may be used.

- The CR module may generate several possible manoeuvres.

- The CR manoeuvre(s) is/are immediately presented to the pilot and at his/her discretion either executed through the autopilot (Mode Control Panel) or by manually execution.

- The information about the manoeuvre is also provided to Trajectory Synthesizer (see 9.3.2.4)**.**

2. *Medium Term CR algorithm characteristics:*

- Both state and intent information will be used in the CR algorithm.

- The CR algorithm will generate a resolution trajectory that is conflict-free (including areas) within MTAZ. The conflicting areas outside MTAZ are not taken into account within this step.

- Coordination between conflicting aircraft is not required and is not considered in this A^3 ConOps. If it is decided to include coordination in the Medium Term CR, the appropriate changes of operations must be analyzed and described in detail. However, even in this case the related CR algorithm must always be able to solve conflicts without coordination.

- In absence of coordination, priority rules will be used.

- It is possible to consider some constraint for rejoining the original RBT, e.g., the exit point of the original RBT from LTAZ.

- The CR module will internally generate several possible manoeuvres and will prioritize them. It is a subject of research how (and how many of them) they will be presented to the crew.

- For the choice of a suitable CR manoeuvre the input/output complexity, i.e., a complexity change induced by the manoeuvre, may be considered.

- Within CR trajectory generation several optimization aspects will be considered.

- The proposed new trajectory is provided to the Trajectory Synthesizer for a completion of the RBT update.

9.3.2.4 Trajectory Synthesizer (TS)

- This module will ensure that after all tactical and/or strategic trajectory changes a new consistent (complete) conflict and areas-to-avoid free RBT respecting AFR exit condition (if possible) is constructed and inserted to the FMS. For these purposes it may call other functions. The typical scenarios are:
  - **Short Term (state) CR manoeuvre.** As this manoeuvre must be executed without delay, it is directly sent to the pilot for execution. At the same time the information about the manoeuvre is also sent to the TS, which will generate a connecting conflict free trajectory taking into account the constraints and some level of optimization. This new trajectory is then (after pilot's input) inserted into the FMS.
  - **Medium Term (intent) CR manoeuvre.** While the Intent CR will generate an optimized and conflict free trajectory for the flight within the MTAZ, the TS will ensure the optimization of the connecting trajectory outside of MTAZ.

- In addition, the trajectory synthesizer should also handle the RBT changes initiated by the flight crew. In particular, a modified route inserted into the FMS will be automatically provided to the TS, which can call relevant CD functions to verify that the route is free of conflicts. After this verification, the flight plan may be safely activated.

9.3.2.5 Trajectory management (long term)

- The Trajectory Management module will update the part of the trajectory outside of the MTAZ either when updated weather information is received, user preferences have changed or when some penetration of an area-to-avoid is detected.

- This module will consider the following input:
  - Areas to avoid in LTAZ from Areas information set.
  - Updated weather information (namely wind conditions).
  - FOC and/or flight crew preferences and RBT changes.

- Trajectory modifications generated by this module will not alter the trajectory within the MTAZ.

- The proposed new trajectory is sent to TS module, presented to the pilot, and if accepted uploaded to FMS. When refused the pilot should be able to modify user preferences to generate a new trajectory. The pilot should also be able to modify the proposed new trajectory by altering its parameters before acceptance.

9.3.3 Airborne Collision Avoidance System (ACAS)

- Within the iFly context the A3 ConOps is assumed to work with current ACAS.
- Future development of ASAS technology will need to consider the implementation of the ASAS/ACAS interface.

- Because ASAS and ACAS work differently, there may be conflicting resolution proposals. One of the iFly aims is to identify how large this problem is. However any further study of this issue falls outside the scope of iFly.

9.3.4 Human Machine Interface – Recommended design guidelines

- The effect of the introduction of advanced tools to support the flight crew during the separation manoeuvre related to situational awareness, team situational awareness and vigilance must be addressed. Safety impacts that may result from changes in these areas also have to be addressed.

- Concerning the design of supporting tools (conflict detection and resolution) and its HMI (display) the guidelines as stated in the ICAO circular 249-AN/149 must be followed:
    - The human must be in command.
    - To command effectively, the human must be involved.
    - To be involved, the human must be informed.
    - Functions must be automated only if there is a good reason for doing so.
    - The human must be able to monitor the automated system.
    - Automated systems must, therefore, be predictable.
    - Automated systems must be able to monitor the human operator.
    - Each element of the system must have knowledge of the other’s intent.
    - Automation must be designed to be simple to learn and operate.

  While the calculations will be automated, the decision making process will be left to the human.

9.3.4.1 Mode awareness

- Conflict detection and conflict resolution advisories will be presented to the flight crew in a way that they become aware of what the system is doing and which information comes at which time into play, so that the flight crew can react suitably also in case of a system failure. Attention shall be placed on the effects of automation on pilots’ situational awareness and workload, especially in case of non- normal situations. This will include different kinds of feedback to keep the pilot ‘in-the-loop’.

- ***Tools*** should be designed and integrated into the cockpit environment in such a manner that:
    - Their functionality and use can easily be comprehended.
    - They do not compete or conflict with existing cockpit equipment.
    - They do not require too much attention, since this would result in increased head-down time and less attention attributed to other tasks.
    - Tools shall be considered as an immediate means of communication, clearly representing the planning without the need of additional verbal communication.
    - Information depicted on a display shall be well organized, clear, unambiguous and easy to read.

  - New supporting tools should contain visual as well as aural alerts which shall not conflict with existing cockpit equipment.
  - The use of Airborne Traffic SA tools shall have no negative effect on flight crew performance and SA. Traffic shall be displayed in intuitive formats.
  - Future conflicts shall be indicated in an accurate, effective and timely manner.
  - Information processing bottlenecks will be mitigated.
  - New or redesigned tools shall have compatible formats.

9.3.4.2 Traffic awareness

- To ensure a high level of traffic situational awareness:
  - All traffic in the vicinity of the own-ship shall be displayed appropriately on a Cockpit Display of Traffic Information (CDTI[27]).
  - The solution advisories and possible new alerts shall not conflict with each other and shall not lead to confusing situations for the flight crew which could be critical to safety.

9.3.4.3 Conflict Resolution

- The airborne decision support tools assist the flight crew in their new self separation task. CD&R advisories shall have the following desirable characteristics:
  - CD&R advisories should be inline with flight crews' way of thinking.
  - Resolution manoeuvres should be straightforward and especially Short Term CR advisories should be designed according to existing flight rules;
  - The ability to specify priorities (e.g. fuel, time, weather, comfort, etc) in the calculation of conflict resolution advisories should be investigated (the flight crew must be kept in the loop. They have to know how accurate the information within the algorithm is, and if this information reflects the actual situation).
  - In case of missing/wrong information (e.g. no weather information available, no information of congested areas, etc) the flight crew must be informed.

9.3.4.4 CDTI – basic functionality

- To perform airborne self separation, the cockpit crew must have accurate information on the surrounding traffic[28].

- A CDTI shall assist the flight crew in performing their self separation task. Information requirements for the HMI and CDTI concerning the following subtasks have to be defined:
  - Traffic monitoring
  - Conflict prevention
  - Conflict detection

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[27] See CDTI section (9.3.4.1.4) for specifications.

[28] Today's cockpit does not provide sufficient information to aid in this task – a change in cockpit avionics is a necessity to introduce the proposed ATM concept.

  - Conflict resolution
  - Replanning
  - Inter-traffic/ traffic-FOC communication

Some of the information requirements needed in order to accomplish each of the subtasks are explained in the following points:

- ***Traffic Monitoring (to assist Perception)***. The CDTI should include the following functions:
  - Indicate traffic position.
  - Indicate traffic speeds.
  - Indicate identification of traffic: call sign or SSR code.
  - Indicate aircraft future state: based on intent or state information.
  - Indicate direction and attitude: track, climb/descent rate.
  - Traffic information shall be in the same frame as the navigation information.
  - An indication shall be given concerning the level of accuracy of the data (state or intent based information shall be indicated).
  - The crew should be able to de-clutter (deselect) the traffic information manually.
  - The capability of selecting of altitude bands should be provided for conflict de-clutter.

- ***Conflict Prevention***. Conflict Prevention tools should assist the crew in the decision making process. The system predicts which manoeuvres will lead to a conflict before these manoeuvres are executed. Several studies have shown the usability of presenting the information of such a system in the form of "no-go" bands on speed, heading and vertical speed tape. Indications of such "no-go" bands must not conflict with other alerts/information and must not lead to confusion which could have impact on safety. Other implementations include FMS integrated prevention systems that poll for conflicts on the modified route. Some of the information that might be displayed for the purpose of Conflict Prevention will:
  - Show unsuitable headings, climb/descent sense and rates, speed ranges so as to avoid short term conflicts.
  - Show conflict zones.
  - Show high density traffic areas (overloaded areas in SSA) – Congestion Prediction.
  - Show hazardous areas.
  - Show specific areas in SSA: segregated areas, density of traffic in entry/exit points/areas.
  - Show SSA boundaries.
  - Show projected information (e.g. separation requirements along route for aircraft, objects and airspace; deviation between separation and prescribed limits; relative projected aircraft routes; relative timing across routes).

- ***Conflict Detection (to assist Comprehension):***
  - In case of conflicts the flight crew shall be alerted in a way which will also be effective when the flight crew is not monitoring a specific display (e.g. aural alert).

    - Information about the conflict shall be provided: when, where, who and nature of conflict.
    - In case of multiple simultaneous conflicts a priority order should be indicated (for use by 1-on-1 conflict resolution algorithms – mainly at Medium Term CD&R).
    - A clear indication as to which of the aircraft involved in the conflict has priority will be provided (i.e. when using priority rules or due to an emergency).
    - It is necessary to provide transparency as to why the system predicts the conflict.

- ***Conflict Resolution (to assist Projection).*** The CD&R system shall:
    - Provide the crew with the means to be informed about and choose among various CR options.
    - Assist the crew in the execution of resolution manoeuvres (the flight crew shall always be in command).
    - The final decision making in CD&R is up to the flight crew.
    - If required, the CDTI must show:
        - The resolution manoeuvres of other aircraft
        - Back-up options (fail-safe), in order to increase safety
        - The impact of potential route changes (e.g. amount of changes required; aircraft capabilities to perform changes; increase/decrease in length of route; cost/benefit of changes; impact of proposed change on: aircraft separation, arrival requirements, number of potential conflicts, aircraft fuel and comfort)
        - The time limit to perform a manoeuvre

- ***Replanning (assists Projection)***: the tools for replanning the trajectory after a CD&R situation (Trajectory Synthesizer) will enable the flight crew to determine the best moment of recovery, i.e. when they can return to their original intended path, if this is required, taking into account that the recovery manoeuvre should be part of the conflict solution.

- ***Inter-traffic/ traffic-FOC communications:***
    - Data Link and SWIM interfaces will be the primary means for communication for flight crews. Operations are designed in a way that direct communication between flight crews is not necessary in regular operations, but there is the provision for establishing contact through these means in case of need. Radio will be preserved as a backup for aircraft-aircraft communications.
    - Communications with FOC and ANSP (to negotiate CTAs) are also performed through data link, with radio as a backup.
    - The messages will make extensive use of the interaction between FMS, CDTI and the communications equipment in order to allow for a quick and easy transfer of RBT parameters and other data.
    - The call sign/SSR code will be provided on the traffic information display to identify other aircraft and to enable the crew to contact them in case of need (the call sign is also useful for crew coordination within own ship).

    - In addition to Air-Air Data Link, a R/T frequency band will be devoted to flight crew contingency and emergency communications, with the development of the specific rules regarding the use of this R/T frequencies falling outside the scope of the A^3 ConOps.

9.3.4.5 General requirements for the CDTI design:

- Minimize impact on cockpit (cockpit layout, new hardware, changes in existing equipment, etc).

- Minimize clutter; traffic symbols should present as much information as possible (necessary) without clutter.

- Provide crew with means to configure display with respect to:
    - Displayed information;
    - Selected range (e.g. long range can be used for conflict detection, and short range could be used for conflict resolution).

- Minimize training demands.

- Minimize human misunderstanding and action errors by an ergonomic study of the display and the interfaces, e.g.:
    - The CDTI might be located in the pilots' primary scan zone.
    - The CDTI shall have an acceptable size, resolution, visibility… etc.

- Minimize crew actions.

- Keep consistency in the display of information of different sources (e.g. Surveillance vs. ACAS data)

- Concerning collision alerts:
    - Display Traffic Alerts (TA) with the relevant associated trajectories.
    - Clearly indicate when passing from Separation Assurance to Collision Avoidance mode.

- Congested areas, weather development and conflict information has to be integrated in a way that pilots can collect all relevant data and make a proper decision.

- Supporting tools shall enable the comprehension of emergencies/equipment malfunctions and alerts from both, ownship and other traffic operating in the SSA (e.g. equipment affected, flight time on remaining fuel, etc).

- Effects of false alarms on the flight crew and their decisions have to be kept in mind.

9.3.4.6 General issues regarding Flight Deck integration of Airborne Traffic Management systems:

- The airborne system will be integrated with the avionics system of the aircraft in such a way that the system has access to current aircraft state, autoflight mode, aircraft configuration and performance, surveillance information, navigation capabilities, constraints, and programmed trajectory information when available and relevant.

- The ASAS system is independent from any Aircraft Collision Avoidance System (ACAS), and yet the two systems should be designed to be inter-operable and non-conflicting.

9.3.4.7 Workload

- Pilot's workload shall be kept within acceptable limits. Therefore it is needed to:
    - Correctly define the procedures (covering normal procedures in SSA and contingency & emergency events);
    - Develop reliable systems including safety and warning tools;
    - Develop emergency and recovery procedures for Emergency and Non-Normal events;
    - Assess and formulate task distribution within the cockpit crew;
    - In order to minimize the additional demands required to gather and process the additional information, the choice of contents and the mode of display are crucial concerns that need to be taken into account at an early stage of the HMI design, and;
    - Self separation shall be easy to handle; for instance, input of new data into the system should be as easy as possible, should not create an increase in workload, should not lead to long head down time.
    - False alarms have to be considered.

9.3.4.8 Training

- Pilots as well as Air Traffic Controllers must be familiarized with all changes that will arise due to their new or changed responsibilities and tasks. This familiarization shall include changes in operational procedures as well as the usage of new or changed equipment.

- In order to ensure a high level of safety all identified stakeholders have to be provided with suitable trainings to strengthen their confidence in and deepen their knowledge of new procedures and supporting tools.

CHAPTER III Regulations and Conclusions

10 Regulations

10.1 Background on ASAS regulations

In order to establish a regulatory background to the A^3 ConOps, the current and future developments in regulations have been assessed. It has been decided to focus on ICAO practices, since this organization provides the most internationally accepted legal and regulatory background for ATM.

If the practices, methods, technologies, rules and procedures presented in this ConOps were to be put into practice, the text contained in the following documents will be susceptible to change, which in some cases will be quite extensive.

ICAO has taken some steps towards the assimilation and standardisation of Airborne Separation Assistance Systems (ASAS):

- 1995 – Presentation of ASAS at ICAO.

- 2003 – the 11th Air Navigation Conference endorsed the global ATM concept introducing the separator either airborne or on the ground and agreed upon:
    - ADS-B concept of use and the ASAS circular
    - A timeline towards stardardisation:

	2006 – 2008	2010 – 2012	2014+
Annex 10	High level ADS-B SARPs ADS-B out already!	-	Airborne Surveillance Systems
Technical Specifications	Air derived data	ASAS	RSP for airborne surveillance applications
Operational Specifications	Phraseology for 3rd parties Concept of use	ATSA-VSA Provisions ASAS-ITP Provisions	S&M Provisions

The current work being undertaken by ICAO on ASAS applications and technologies comprises the following initiatives:

- The Separation and Airspace Safety Panel (SASP) has produced the Separation Minima Standards for ADS-B (5 NM) - Provisions are being taken for PANS-ATM (Doc 4444).

- The Operations Panel (OPSP) is responsible for aircraft operations and is dealing with the introduction of a CDTI, as well as phraseology for third parties – Provisions for PANS-OPS (Doc 8168).

- The Aeronautical Surveillance Panel (ASP) is working on ADS-B requirements on 1090 MHz both from ground and airborne perspectives and is in charge of the development of the Required Surveillance Performance (RSP) – Annex 10 for High level, detailed specs on Doc 9871.

- ICAO will express SARPs based on required performance for CNS systems and for the system as a whole.

- RSPs are already in place; RSPs are being developed regarding the following items:
    - RSP value
    - Accuracy
    - Reliability
    - Integrity
    - Latency
    - Update Rate
    - Continuity
    - Coverage

- Starting in 2008, ICAO will publish material relative to the display of ACAS targets on multi-purpose traffic displays.

- Work is being undertaken in the high level definition of data provided by aircraft ADS-B-in.

- In a medium-scale timeframe, ICAO expects to produce:
    - Airborne surveillance SARPs
    - RSP to support airborne surveillance
    - Technical Specifications for the use of CDTI for manoeuvres in uncontrolled airspace
    - ATSA-ITP standard for 2009/2010
    - Merging and Spacing (ASPA-M&S) for 2011

The challenge for ICAO is as follows: how to ensure global interoperatibility of ASAS applications without dictating detailed or specific solutions to industry. Regarding this, ICAO believes that RSP and PANS will be sufficient to derive ASAS architectural solutions.

It may be preferable to gain some experience with new systems thanks to some pioneering – although limited – applications before standardization, as it happened with ACAS: TCAS existed before ACAS was standardized and mandated.

The legal aspects of ASAS applications will be focused on the three stages of Traffic Conflict Management:

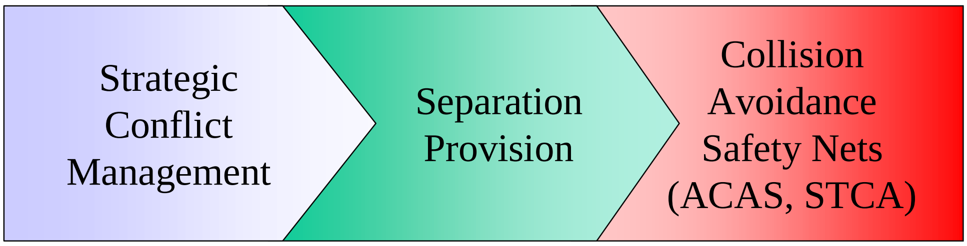


Figure 10-1 Traffic Conflict Management Stages

Self separation applications are still quite away from ICAO's current scope; nevertheless, the current and subsequent efforts will eventually allow for the implementation of some forms of self separation, through:

- Operational experience derived from the pioneering forms of ASAS applications, in:
  - Man-hours and equipment cycles
  - The definition and clarification of roles and responsibilities
  - The refinement in the design and performance of equipment, rules and procedures
  - The mistakes and errors that will surely be made and corrected

- Application of the rules of the air, standards and recommended practices and their subsequent refinement.

- Change in the current ATM paradigm with the implementation of a more flexible and user-oriented ATM system.

There is currently no solid effort being undertaken to establish self separation operationally by ICAO or other governing agencies; this is due to the lack of a solid ground regarding the application of ASAS technology in this field, as well as to the fact that ASAS applications are still in their relative infancy. The iFly project aims to provide a foundation for future developments of self separation by taking a look into self separation as an established mode of operations.

10.2 Considerations about self separation regulations

10.2.1 Operational environment

The A^3 ConOps provides insight in some crucial areas regarding the operational environment that has been defined:

- ***Development of specific new classes of airspace:*** SSA airspace has been defined in order to accommodate pure AFR operations.

- ***Standards for airborne separation minima:*** they are provided through the definition of the characteristics of Protected Airspace Zones.

- ***Specific flight rules:*** AFR flight rules have been defined, and it has been clearly stated that aircraft have to abide to them in order to be able to operate autonomously in SSA.

These aspects, along with specific rules for airspace access (which are not considered in this ConOps), have to be upheld by mirroring regulations, which will be expected to provide, in the ConOps application time frame, standardisation at international level in order to allow aircraft operators to obtain the expected benefits that result from the concept.

The operational environment that this ConOps presents can be considered as radically different from the one considered in the current ATM paradigm. Although this is in many ways not completely true, it is recognized that, given the nature of regulatory texts, the changes needed to be applied to them will be extensive and that it will take some time to accomplish this work.

10.2.2 Separation Responsibility

In order to apply a concept of operations, the responsibility areas for the different actors present in the concept have to be delimited, so that there is no doubt as to which parcel of responsibility is allocated to each actor of the concept.

In self separation, the key area of responsibility lies with the flight crew, which is considered solely responsible for the flight safety with regard to the en-route phase of flight; this is translated, in the ATM environment, to avoid violation of a set of minimum distances (separation minima) from the aircraft to the objects present in this environment (traffic, areas-to-avoid, etc). This is called self separation when:

- The flight crew ensures separation of their aircraft from all surrounding traffic (and possibly other objects).

- The controller has no responsibility for separation.

A consolidated set of flight rules (AFR), which the aircraft will have to abide to, will need to be upheld by regulatory bodies when the time for implementation of self separation comes; responsibility distribution has to remain clear in all situations to all actors following from the application of this set of rules. The inherent internationality of the ATM paradigm proposed determines that it is up to international regulatory organisms (i.e. mainly ICAO) to provide the regulations framework needed to apply a concept of operations such as this.

As it is supposed that airborne separation will be maintained by the flight crew’s appliance of standardised separation minima, the establishment of these ‘airborne separation minima’ in order to maintain safe operations is a major issue at an international level. It is possible that current ATC radar separation minima could be greatly reduced through the application of a self separation paradigm, thus allowing for large capacity increases; but this will give a much greater importance to the study of some issues that have remained largely untouched, such as en-route wake vortex encounters.

10.2.3 ACAS & self separation interactions

The interactions of self separation systems with airborne collision avoidance are of the greatest importance to ensure the overall safety level of the ATM system. Since it is conceivable that ACAS might start providing collision avoidance alerts and advisories before the applicable separation minimum has been infringed, it is essential to establish adequate regulation regarding both using ASAS and ACAS.

Some of the aspects to be considered are:

- ***Priority of ACAS over ASAS:*** It is obvious that, under a certain time-to-collision range, ACAS should have priority over ASAS. Inversely, ASAS will have priority over ACAS if the conflict is detected sufficiently in advance. However, there is a time-to-collision zone between these two extremes where priority of one system over the other could be unclear.

- ***Nature of ACAS and ASAS resolutions:*** Regulations should explicitly state that the resolutions for collision alerts (ACAS) and detected conflicts (ASAS) will be compatible in the time-range where both layers overlap.

10.2.4 Separation assurance requirements transference

In Section 8.11 of this document (Non-normal and Emergency operations), it is stated that, when an aircraft is not capable of autonomous flight, '*other aircraft will have to perform all separation requirements regarding that particular aircraft when it still is inside SSA*'. This is possible because the nature of the proposed ATM system is such that it operates as a distributed and redundant system. This makes this approach more fail-safe than other, more centralized, alternatives. Since every aircraft, apart from the non-self separation capable one, retains its individual capabilities, the failure of one aircraft can be compensated by the rest of the elements of the system.

From the regulatory perspective, this implies that, in the case of one aircraft losing self separation capabilities, *there is not a transfer of separation responsibility* from the flight crew of that aircraft to the rest. Unlike having to rely on external, ground-based ATC (and having to perform a *separation responsibility transference* under what can be critical conditions for the affected flight crew), the other flight crews are, in the same way as before, responsible for maintaining separation, because they already were invested with separation responsibility from all traffic. The flight crew which has lost their ability to perform the self separation task is relieved of any kind of responsibility as it can no longer perform this task

In such a system, then, what happens in these situations is a *separation assurance requirements transference,* from the troubled aircraft's flight crew to all neighbouring traffic crews. This loosens the requirements for the procedures to be implemented in these cases, liberating the troubled flight crew from additional workload, and providing greater freedom to the nearby traffic crews. Regulatory texts on this matter will have to reflect this different approach to non-normal and emergency situations.

10.2.5 Manufacturers and ATSEP responsibility

In order to be able to present standards to the aeronautical manufacturers and maintenance personnel communities, that ensure safety for air transport and at the same time allow for continuing development and innovation, the current thread among regulatory bodies is to provide all parts affected with performance standards requirements, rather than specific solutions in order to achieve these standards. Therefore, any technical solution that is up to the required performance level can be implemented, and this allows for greater initiative in the development of new equipment. The instauration of a self separation ATM paradigm will only be possible if extensive areas in avionics, automation, human/machine interfaces are developed in ways that are nowadays only hinted at; and this will only be possible if the regulatory framework for manufacturers and technology developers is favourable to them.

The implementation of extensive automation in the cockpit arises an issue in responsibility distribution: if, for example, the flight crew is following the trajectory modification advisories an automated CD&R system is presenting them with, and a loss of separation occurs, who should be made responsible cannot be determined trivially. Probably a distributed concept in which all actors involved have a particular area of responsibility should be applied, but this will bring additional complexity to the problem. This will affect equipment manufacturers and ATSEP (Air Traffic Safety Electronics Personnel), and it is envisioned that future regulations will include these actors in the distribution of responsibility. As it is said in SESAR D4: '*To increase capacity and efficiency, advanced automation will support or may even take over specific human tasks. The situation awareness of controllers, ATSEPS and pilots will therefore change. As a consequence, human operators will not any longer be in a position to take over manually in case of automation degradation. In many cases, specifically designed secondary automation will have to function as a fallback in case the primary automation fails. Legal accountability and liability (for example in case of malfunctions, incidents and accidents) will in those cases shift from the current end users (typically pilots and air traffic controllers) to the system designers, manufacturers and maintenance engineers.*'[29] However, at this point it is still adventurous to point the direction of these future developments.

[29] SESAR Definition Phase: Deliverable 4, ATM Deployment Sequence, DLM-0706-001-00-008

11 Concluding remarks

This section summarizes the objective of this report, the A^3 ConOps developed, and the follow-on work on refining the A^3 ConOps within the iFly project.

11.1 Objective of this report

The objective of this report has been to provide a description of an Autonomous Aircraft Advanced (A^3) ConOps which can safely accommodate a factor three to six times more traffic then at current busy traffic levels. The current state-of-the-art in Airborne Separation Assistance System (ASAS) research, future advanced Air Traffic Management (ATM) research environments (SESAR and NextGen), as well as previously released deliverables from WP1 (High level A^3 ConOps report D1.1) and WP2 (Human factors analysis reports D2.1 and D2.2) have been used as a starting point for the description of the A^3 ConOps.

This report is a key deliverable in the iFly project, as it provides the input for those Work Packages which will either focus on developing technologies whose requirements arise from the ConOps (WPs 3, 4 & 5), or will perform cost/benefit and risk/safety assessments of the ConOps itself (WPs 6 & 7).

11.2 A^3 ConOps developed

The A^3 ConOps can be seen as a conceptual description of a future (2025+) airborne self separation operation in the en-route phase of flight. The flight crews of such aircraft will be able to ensure separation from neighboring traffic and other obstacles, without the assistance of ground-based Air Traffic Control (ATC). This is enabled by advanced airborne systems with new surveillance and trajectory management capabilities and new ground automation. In addition to separation management these systems allow for effective trajectory optimization, while meeting traffic flow constraints.

The users of the A^3 ConOps may take part in a net-centric environment through the inclusion of a System Wide Information Management (SWIM) network, in which users share a common picture of operational information, allowing them to identify the course of action that is both feasible and best matches their needs. Information that is shared will include aircraft trajectories, surveillance data, constraints, aeronautical information and meteorological data.

The A^3 ConOps introduces the concept of Self Separating Airspace (SSA) where the separator is the airspace user. In SSA all aircraft are electronicaly visible by means of both direct Air - Air Data Link (DL) and ground uplink and are responsible for separation, in accordance with pre-defined Autonomous Flight Rules (AFR) through SWIM. Information from both air and ground can be used by on-board systems for Long Term Area avoidance, Medium and Short Term Conflict Detection & Resolution, Conflict Prevention and Collision Avoidance. The on-board systems will also include functions to detect and avoid areas of high traffic complexity. Combined with an airborne Trajectory Management unit the system will provide trajectories optimized for safety, efficiency and passenger comfort.

Within the scope of the concept, an A^3 flight is defined as the flight between a departing Terminal Area (TMA) exit point, and an arriving TMA entry point, constrained by a Controlled Time of Arrival (CTA) at the arriving TMA entry point. Along the flight, the aircraft will broadcast its own state and intent, separation class and priority level through Air – Air Datalink. Updates of this information together with RBT updates will also be communicated to SWIM. Received data from other aircraft, augmented with data from SWIM, will be fused with data from onboard sensors to achieve traffic SA and perform the required surveillance functions.

Dedicated Decision Support Tool (DST) needs have been defined, which will help reduce mental workload and aid in the decision making process. These tools will make use of all data available according to three predefined timeframes. In the **Short term timeframe –** typically up to 3-5 minutes, own and other aircraft trajectory information is used by a state-based extrapolation. In the **Medium term timeframe –** typically up to 10-20 minutes, the trajectory can be reconstructed from intent data and for the **Long term timeframe –** typically more than 30 minutes, RBT-based data is used. Airborne self separation is only performed within the short and medium term timeframe, the long term timeframe is used for flight optimization and flow management.

The Conflict Detection and Resolution (CD&R) modules for the short and medium term timeframe are designed to work in parallel. The information from the detection modules will be provided to a Conflict Processing unit which will determine the appropriate resolution module. Based on the time to loss of separation, resolutions will be presented as modifications of the FMS flight path or as tactical heading, speed and/or altitude changes. The need for an independent collision avoidance system has been defined. It is considered that this system could be potentially integrated with very short term (~1 min) state based separation assurance with collision avoidance in order to enable a smooth transition from ASAS to ACAS functionalities and to ensure compatible resolution advisories.

The A^3 ConOps also defines procedures to accommodate non-normal, emergency and non-civilian operations. These operations are made possible through the introduction of separation classes, priority rules and the definition of restricted airspace around aircraft. Aircraft with diminished separation capabilities will indicate their capabilities to other aircraft and to SWIM. As a result the separation class may be altered and the priority level may change, resulting in the fact that the separation responsibility be transferred to other nearby aircraft.

In addition to operational aspects the A^3 ConOps document also provides guidelines in support of Human Factors, Human Machine Interface (HMI) development and operational scenarios, which include examples for normal, non-normal and emergency operations.

11.3 Follow-on work

As previously stated, this report is a key deliverable in the iFly project, as it provides the input for other Work Packages. WP2 performs a human factors oriented critical analysis of the A^3 ConOps and subsequently develops proposals for its improvement. In WP3 the ConOps will be used to study and develop methods for the timely prediction of potentially complex traffic conditions. WP4 will use the A^3 ConOps in developing techniques for detecting possible situation awareness mismatches between autonomous agents in autonomous flight control scheme and determine whether the ConOps is viable in view of these potential situation awareness mismatches. WP5 will use the ConOps as a baseline to investigate and push the limits of conflict resolution algorithms. The operational benefits and costs associated with the introduction of A^3 the concept will be identified in WP6. This WP will also determine the conditions under which the proposed concept is viable. In WP7 the A^3 ConOps will be assessed to determine what traffic demand can safely be accommodated by this advanced operational concept. This analysis is done through hazard identification and Monte Carlo simulation on accident risk as a function of traffic demand. WP8 and WP9 will further refine the A^3 ConOps using the outcome of WP2 through WP7, and WP9 will also develop preliminary Airborne system design requirements.

Appendices

I Operational Scenarios

This appendix provides some example Operational Scenarios which showcase some of the possibly challenges posed to the A^3 ConOps. It is important to note that these scenarios are not intended to be hard requirements for other WPs; they are merely presented to identify some of the potential situations for which the A^3 ConOps may be evaluated.

This ConOps presents a generic ATM paradigm that can, in principle, be implemented in any geographical location and therefore the Operational Scenarios do not provide a specific geographical location for each of the examples given. Researchers can opt to choose a geographical setting according to their specific needs.

The operational scenarios are selected based on the following two criteria:

- ***Likelihood:*** whether the particular operational scenario is most likely to occur, it will have a higher score in this aspect.

- ***Operational Impact:*** if the situation described may potentially lead to a bigger and/or more critical impact in the operations as described in the A^3 ConOps, it will score higher.

The chosen scenarios are further classified in Baseline Operational Scenario (Normal), Specific Configuration Scenarios, Event Driven Scenarios, Intruder Based Scenarios and Reduced Performance Scenarios.

I.1 Baseline Operational Scenario

The Baseline Operational Scenario is intended to assess the global performance of the proposed ConOps under normal operative conditions. Prerequisite is that a sufficiently large number of aircraft is represented, in order to have a realistic representation of traffic flow through the considered area.

The characteristics of this scenario include:

- An ‘unconstrained’ airspace, with no weather, restricted airspace or terrain areas (for a more realistic approach, static areas-to-avoid may be included).

- A set of TMAs where aircraft depart from and arrive to.

- An ‘a priori’ Conflict-free trajectories arrangement.

- A representative variety of aircraft types and airlines (these will impact upon the overall behaviour of the system through FOC/own fleet interaction).

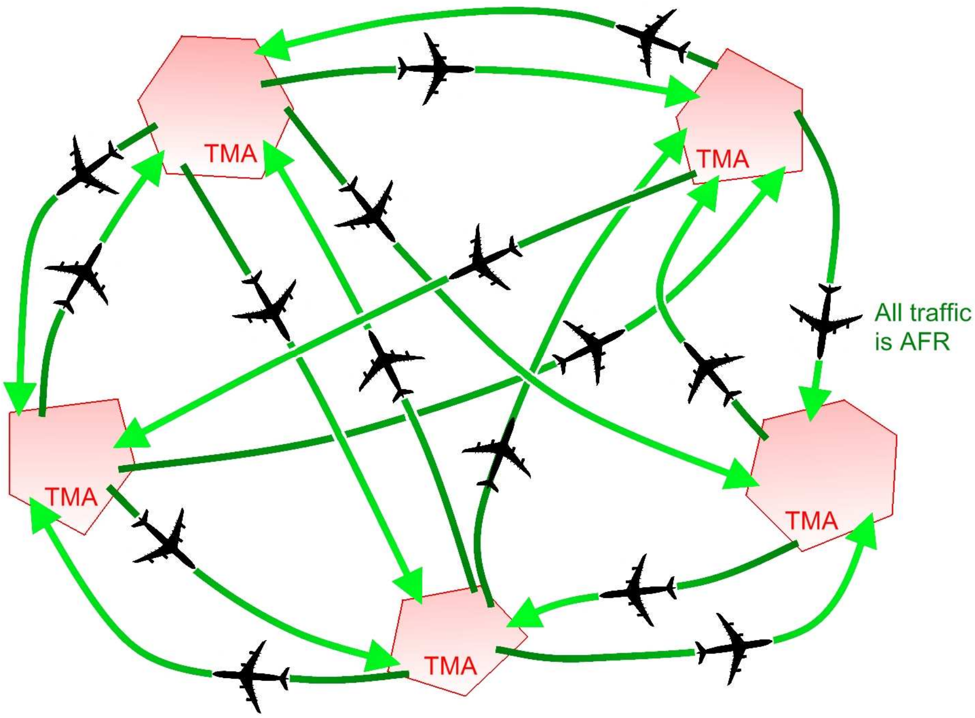


Figure I - 1 Baseline Operational Scenario

These characteristics can be used to assess traffic behaviour in terms of:

- Traffic density (this will be an independent variable of the scenario, in order to assess performances vs. capacity).
- Capacity (the maximum traffic density obtained while maintaing a pre-determined safety level).
- Safety (closest point of approach, conflicts and Losses of Separation as a function of traffic density).
- Efficiency (CTA meeting as a function of traffic density, statistics on aircraft trajectory deviation).
- Traffic flow structure (different TMA configurations to study and to evaluate different traffic flow patterns).
- Complexity (an intrinsic airspace complexity metric can be applied to measure overall traffic complexity).

Aircraft will enter the scenario at the origin TMA exit point and leave the scenario once they transition into the destination TMA. A^3 ConOps functionalities that are expected to be used in this scenario are:

- Pre-flight CDM process in order to produce a strategically deconflicted traffic flow.
- ASAS and trajectory management capabilities (full-scale or simplified) for every aircraft.

- Envisioned communications and surveillance capabilities for every aircraft.
- ATM Ground Support utilities (complexity and congestion prediction, traffic proximity detection).
- CTA (and time windows) assignment at the arriving TMAs.

This scenario will assess the general operation in SSA, therefore the A^3 implementation detail (or aircraft flight performances modelling) is expected to be the highest possible as well as the number of modelled aircraft.

The scenario can also be scaled down in order to present different traffic configurations for the evaluation of Conflict Detection and Resolution algorithms performance. Here, the modelling detail of aircraft behaviour could be increased to more precisely evaluate the 'quality' of the CR manoeuvres.

I.2 Specific Configuration Scenarios

I.2.1 Dynamically changing weather scenario

The first operational scenario aims to assess A^3 performances using a static traffic flow configuration (essentially, not time-dependant; although each aircraft is following a trajectory – and solving conflicts – the overall traffic flow can be considered to be static). In order to assess A^3 performances in a more dynamic environment, the flow constraints imposed to the airspace need to be modified.

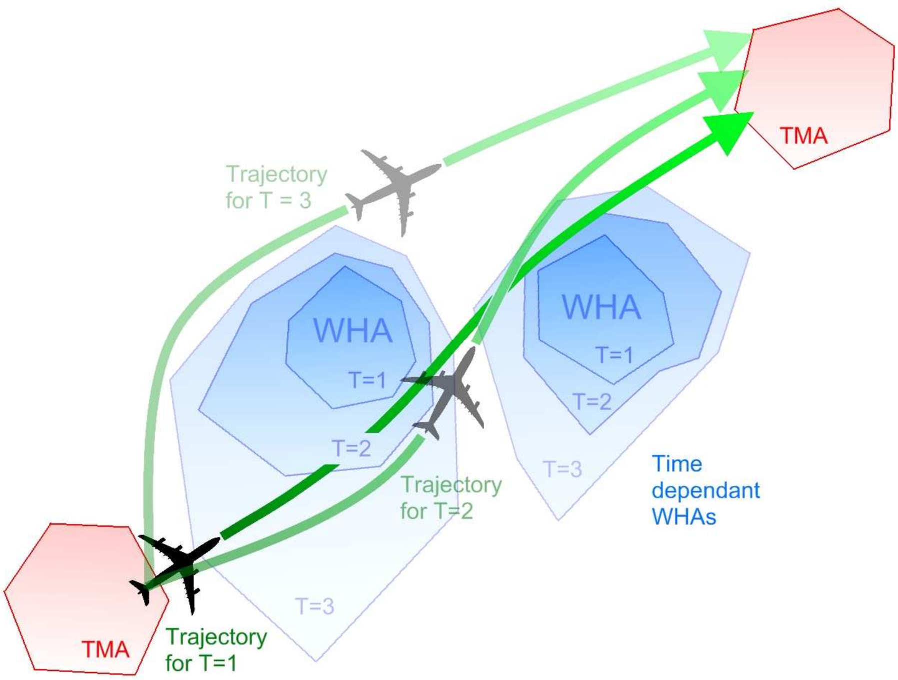


Figure I - 2 Dynamically changing weather constraints

Time-dependant WHAs will be introduced in a scenario similar to the baseline operational scenario in order to assess the following:

- Is the system capable of adjusting to dynamic changes?
- System capacity in the presence of WHA constraints.
- CTA/RTA compliance as a function of time.
- The number, percentage of airspace covered and level of WHA constraints that the system can cope with for a given capacity.
- Interaction of WHA with complex/congested areas which can either be:
    - Introduced ‘a priori’
    - Generated by the system’s behaviour under changing conditions

Some aspects of this scenario that can be modified for further assessment are:

- Part of the flight where the weather constraints change – is it in the middle of the en-route flight, or closer to a TMA?
- Time that aircraft have to react to WHA appearance – do they appear on the LTAZ, or close to the aircraft?

In addition to the baseline A^3 ConOps functionalities that have been listed in the baseline operational scenario, the following more specific functionalities will play an important part:

- ATM Ground Support performances.
- Fusion of weather data from ground based forecasts and airborne weather radar.
- ASAS and Trajectory Management performances in the presence of time-dependant trajectory constraints.
- Dynamic CTA reallocation to those aircraft which are not capable of making their assigned CTA.
- SWIM and Air-Air Data Link update rate and information quality.

I.2.2 Interfering TMAs Scenario

This scenario is designed to evaluate the interference between two traffic flows into adjacent TMAs, which may produce conflicts as a result of the TMA entry configuration.

The scenario design will feature the following elements:

- Two crossing traffic flows in which aircraft are closely spaced.
- A CTA arrangement that may produce conflicts at the traffic flow intersection point.

This arrangement will result in aircraft having to react to conflicts, which may disrupt the traffic flows (and henceforth CTA/RTA compliance).

Some of the parameters that have to be determined for this scenario are:

- TMA arrangement (distance between both TMAs, TMA configuration, area coverage).
- Airport traffic.
- TMAs with single or multiple airports configuration.

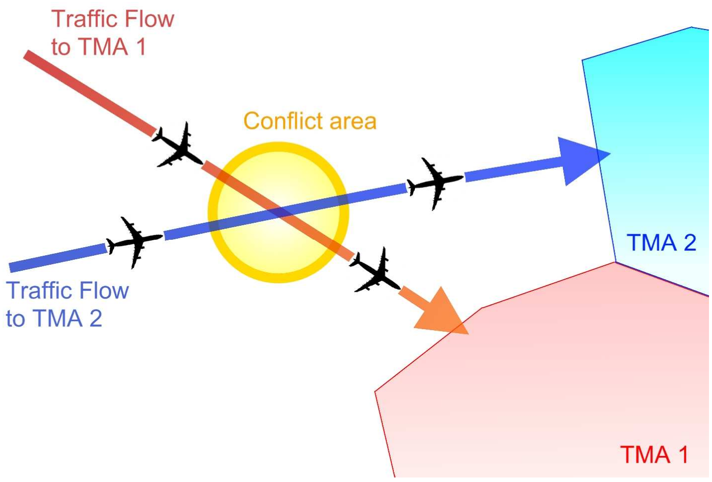


Figure I - 3 Interfering TMAs

The issues to be investigated, involving A^3 ConOps performance in this scenario include:

- Explore the system's inherent capabilities to deal with conflicting TMA configurations (CTA/RTA compliance without any additional flow management).

- Explore the performances of CR algorithms, in terms of:
    - Conformance to allocated priority (which will be time-dependant since aircraft are in relative close proximity to TMAs and the CTA time windows will be reducing, with some aircraft locked into AMAN).
    - CR solutions, which have to solve all conflicts while having the least possible impact on CTA compliance.

- Evaluate the need for the introduction of airspace management (in the form of CTA & waypoints constraints) outside the TMAs and/or TMA extension into SSA:
    - What kind of constraint configuration to use
    - How many constraints are needed (the less, the better)
    - Determine the optimal positioning of these constraints (closer or further away from the TMAs)
    - Explore the possibility of addressing the conflict point in the preflight SBT arrangement.

The A^3 functionalities that are predominantly investigated in this scenario are the performances of CR algorithms when aircraft are close to meeting their CTA/RTA.

I.2.3 'Hole in the clouds' Scenario

This scenario is designed in order to evaluate the performance of CR algorithms in a severely laterally constraint airspace. The scenario configuration is as follows:

- A wall of convective weather (Weather Hazardous Areas - WHAs), closes an airspace and leaves only a small opening through which only an organized and structure traffic flow can pass. This element can be either placed mid-route or close to a TMA.
- The aircraft may either choose to go through the opening or go around the WHAs (which will be big enough to cause a significant trajectory change and the possible inability to meet the assigned aircraft CTAs).
- In a more advanced conception, it is possible to envision a 'maze' of WHAs that force aircraft to follow very precise 'corridors' between clouds.
- A time-dependant evolution of this scenario may also be applied, where the pass-through corridor broadens, narrows or disappears altogether.

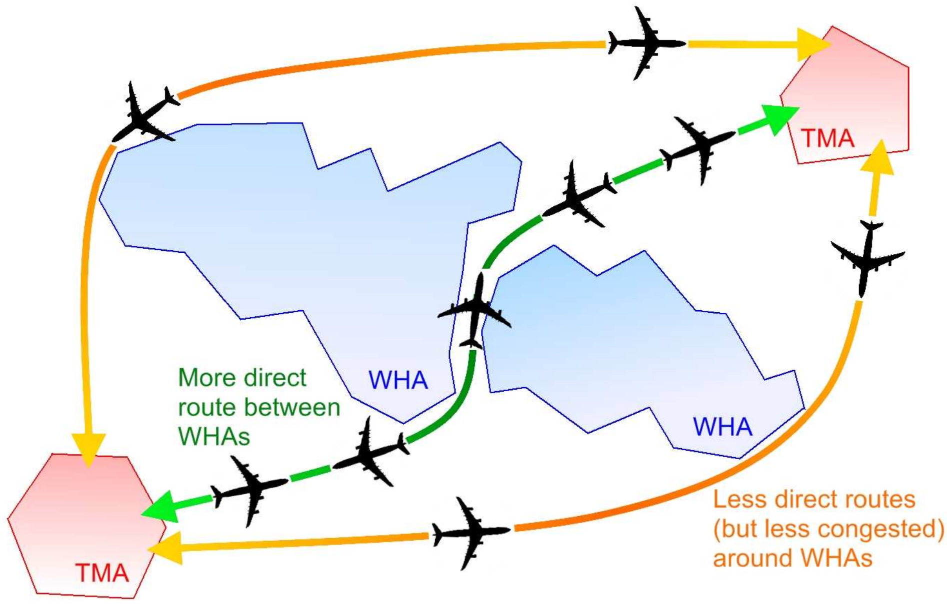


Figure I - 4 'Hole in the clouds' Scenario

The objectives of this operational scenario include:

- Explore the functionalities of CR algorithms to perform under severely laterally constraint conditions.
- Explore maximum capacity levels without the necessity of flow management
- Analyze the dependence of the overall system behaviour on the complexity and density of the airspace.

The most important A^3 functionalities that will be investigated are the performances of the CR algorithms and trajectory management in times when the manoeuvring space is severely constrained in one of the planes.

I.3 Event Driven Scenarios

I.3.1 TMA closure Scenario

To test the transitory performances and flexibility of the A^3 ConOps ATM system, this operational scenario is designed to stage a massive shift in traffic flows, by suddenly closing an important TMA. All aircraft that were flying towards a designated TMA have to be redirected to neighbouring TMAs, which results in a massive new CTA/RTA assignment.

The goal of this scenario is to assess the airspace structure in terms of strategic flow restructuring, and how aircraft cope with sudden appearances of congested and/or complex areas.

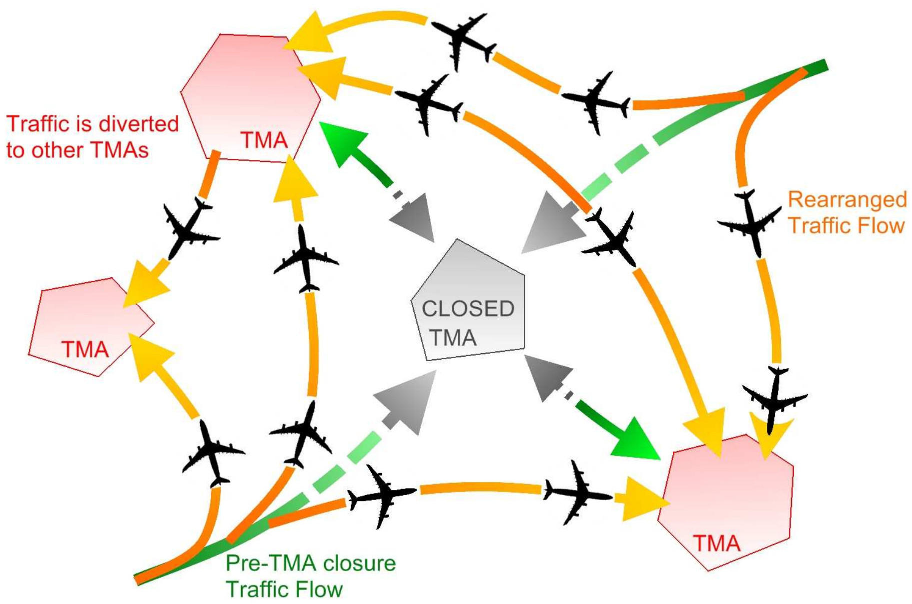


Figure I - 5 TMA Closure Scenario – Flow rearrangement

The scenario configuration will follow the principles outlined in the baseline operational scenario, but place greater importance to the TMA configuration design. Some factors that may have a relative high significance in the design of the scenario include:

- Geographical location and area coverage of the TMAs.
- Aircraft's time to react. How they re-route to the newly assigned TMAs?
- Airport capacity (which will have an impact on CTA assignment).
- TMA entry and exit configurations.
- Introduction of multiple airport TMAs.

The A^3 ConOps related factors that can be analyzed include:

- Assess flight crew and on-board systems performance to deal with the changing situation.
- CTA compliance.
- Interaction with scheduled aircraft arriving at the ‘open’ TMAs, and disturbance produced by the additional re-scheduled aircraft.
- Traffic flows time-dependant structure, and the appearance of complex and/or congested areas.
- Additional conflict rate, compared to baseline levels.

The A^3 functionalities that will be put to the test in this scenario include:

- Trajectory Management and FMS, operating at all time frames (from the long term to the short term) to allow for trajectory modifications while maintaining CTA/RTA compliance.
- SWIM and Data Link communications.
- ATM Ground Based scheduling tools.
- Flight crew abilities to assess and react to a changing situation.

I.3.2 Sudden publication of a RAA Scenario

This scenario is designed to assess the transitory performances of the A^3 ConOps ATM system to deal with the sudden publication of a RAA. Using the baseline operational scenario an RAA unexpectedly appears, covering a volume of airspace and catching all traffic unaware: there will be some aircraft inside it; others about to cross through and others whose RBT will only be affected in the medium and/or long term. All aircraft will react, according to their proximity to the RAA, using whichever CR module is appropiate.

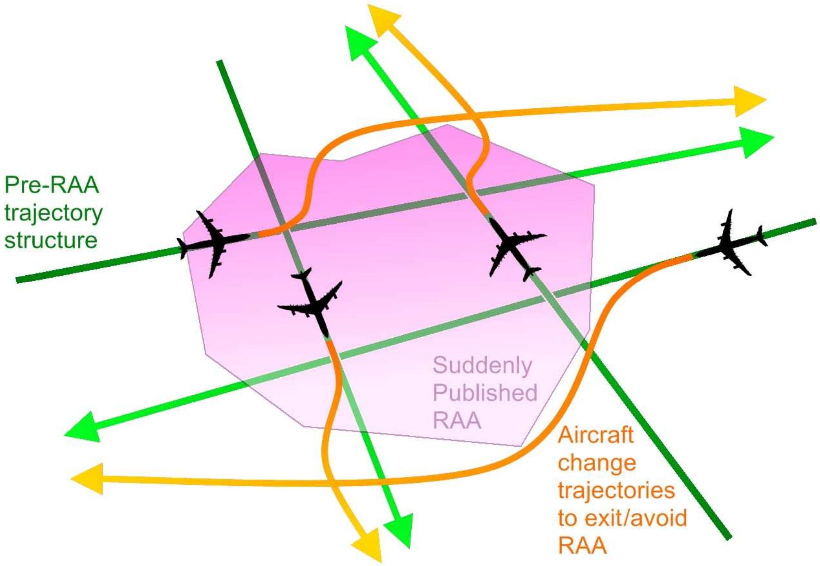


Figure I - 6 Unexpected SWIM update scenario

To evaluate the performance of the system, the following will need to be assessed:

- Time required to resolve conflicts with the RAA (related to the RAA size).
- Flow disturbances, in terms of:
    - CTA/RTA compliance at the arriving TMAs.
    - Efficiency of aircraft trajectories.
- Interaction between areas complexity & congestion prediction and dynamic – but arbitrary – changes to the airspace structure.
- The new flow structure that will appear once the system has again reached a stationary state.

Area CD&R and SWIM communications functionalities will be addressed, as well as Trajectory Management and the interaction between SWIM and the envisioned ATM Ground Support functionalities.

I.4 Intruder Based Scenarios

I.4.1 Air defence fighter interception Scenario

As described under section 8.10.1, when performing intercept missions, fighter aircraft will have to self separate from all traffic while intercepting a target aircraft. This is a result of the fighter aircraft not updating its position. Other aircraft including the intercepted aircraft will not receive surveillance information from the fighter and are therefore not aware of its presence.

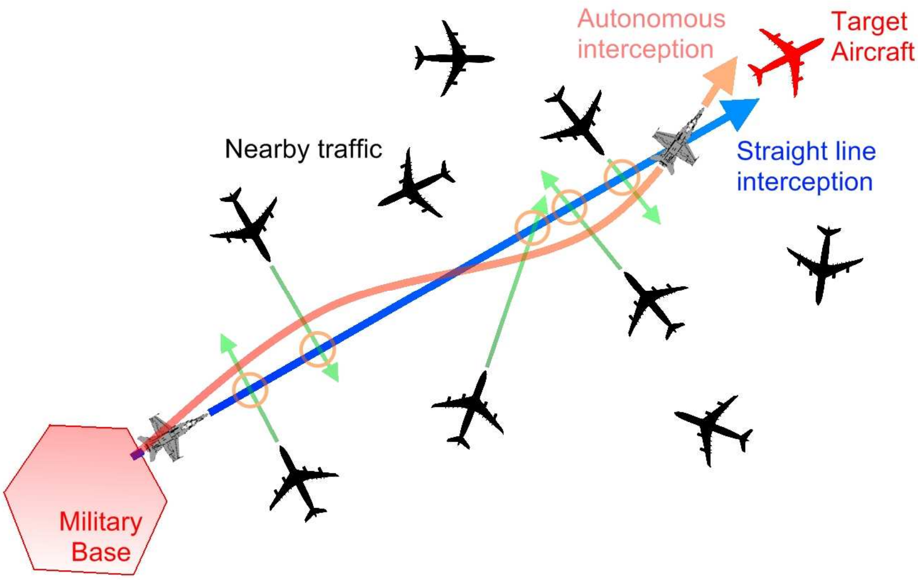


Figure I - 7 Interception of a civil aircraft

Based on a scaled-down baseline operational scenario, this scenario will provide insight into:

- How the task of self separation influences the fighter's mission performances (e.g. time to intercept).
- The introduction of aircraft with different flight envelope and performance characteristics.

All the usual parameters and elements (traffic density and complexity, WHAs, RAAs, etc) can be considered to evaluate this scenario under different conditions.

I.4.2 Fast-moving RAA Scenario

Under Non-normal and Emergency conditions, the A^3 ConOps considers that, if an aircraft is not able to meet AFR requirements, SWIM might provide dynamic RAA around an aircraft and update its position through position reports or radar returns. Aircraft in the vicinity will have to avoid the RAA as if it was an area conflict (see section 8.11.1).

That area will (instead of not moving at all, or moving relatively very slowly) move at the aircraft's speed but, unlike an aircraft, will not provide trajectory information. Airborne systems should be able to infer the area's course and speed by interpolation of current and past positions, but this information would be inaccurate and incomplete when compared to normal aircraft trajectory information. The relatively low update rate of SWIM may further complicate the situation.

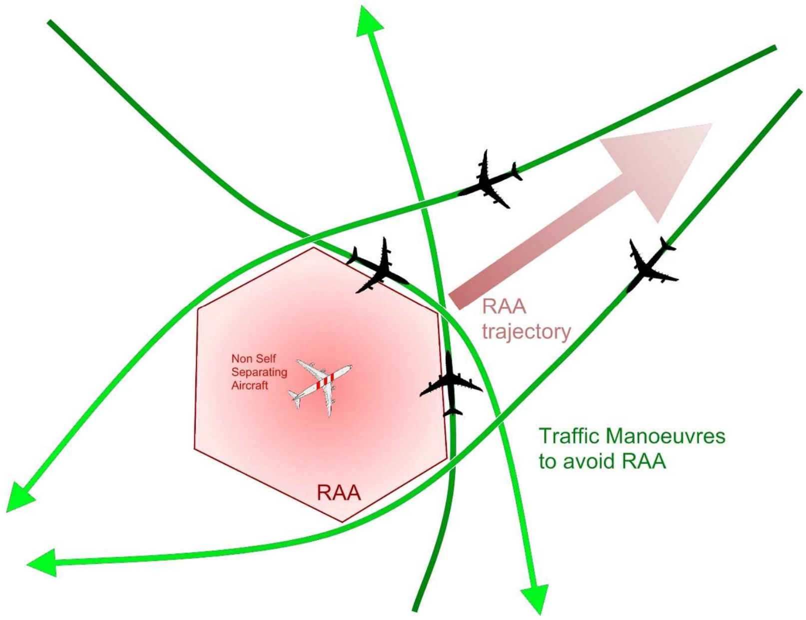


Figure I - 8 Fast moving RAA Scenario

This scenario will consist of a fast-moving RAA to which other aircraft have to react to. The baseline operational scenario can serve as a basis for this scenario. The evaluation will focus on:

- RAA trajectory assessment by surrounding aircraft.
- Area conflict detection and resolution by aircraft.
- Disturbance of the traffic patterns in relation to the RAA size – possible complexity and congestion interactions.
- RAA violations.

The critical functionality evaluated by this scenario will be the Area CD and CR performances; it is expected that, being able to solve a fast-moving RAA conflict, the system will be able to cope with all other area conflicts described in the A^3 ConOps.

I.4.3 Emergency operation Scenario

This scenario will showcase the ATM ConOps abilities to deal with an emergency, or non-normal aircraft, which is no longer capable of self-separating, and therefore required, as stated under 8.11.1, to leave SSA and enter MA as soon as able. All other aircraft will get the burden to separate themselves from this aircraft while it is still inside SSA (the fact that this is possible shows the inherent redundancy of the A^3 ConOps). The behaviour of the proposed ATM system will be evaluated by this or other similar scenarios.

Based on a scaled-down version of the baseline operational scenario, the scenario will include an aircraft which announces an emergency and leaves its broadcasted trajectory and heads for a particular TMA (that can be modelled as an airspace volume the aircraft tries to reach). The level of surveillance information available for that aircraft can range from full communications/surveillance capabilities to just some very basic state information, depending on the nature of the emergency which might have nothing to do with ASAS capabilities.

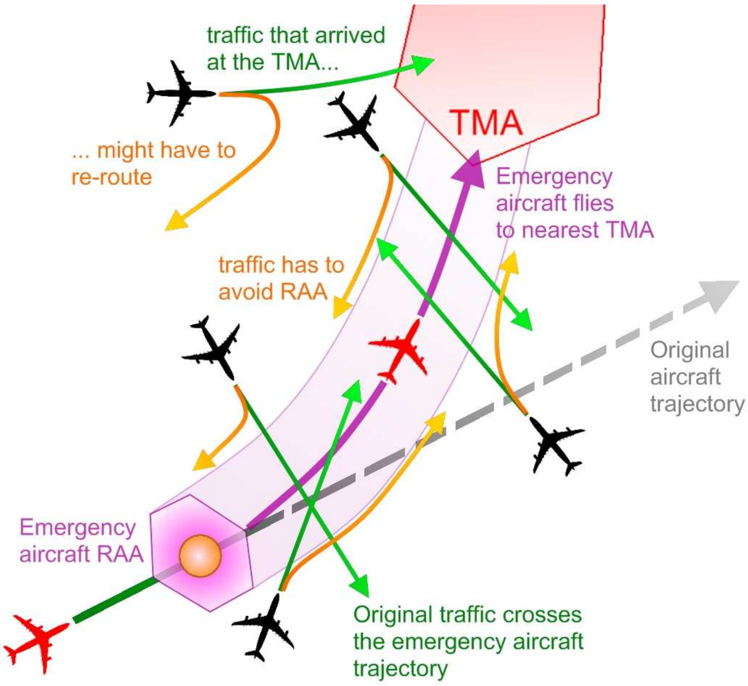


Figure I - 9 Emergency Operation Scenario

Set in various traffic density and complexity environments, the following can be assessed:

- Appearance of short-term conflicts.
- SWIM role:
    - Is the update rate of aircraft surveillance provided by SWIM high enough to deal with these situations?
    - Switching from airborne surveillance to ground-based surveillance.
- The chance of an emergency aircraft encountering non-self separating traffic.
- Time of emergency (mid-route or closer to arriving TMA).
- Impact on the flow structure.
- Time to conflict for other aircraft.
- CTA reassignment at the TMA the emergency aircraft is going to.

The full suit of ASAS capabilities will be assessed in this scenario. An interesting feature is that the scenario can be configured to generate all kinds of simultaneous traffic conflicts.

I.4.4 Rogue aircraft Scenario

In order to assess the redundancy in the proposed ATM system, it is possible to adapt the baseline operational scenario in order to have a certain percentage of aircraft not deviating, for CR reasons, from their broadcasted state and intent. These aircraft will neither be in a non-normal or emergency state, nor will they be experiencing a loss of autonomous performances; it is possible to treat them as 'rogue' aircraft which disregard conflicts and continue to fly their original RBTs. Aircraft can also be given an infinitely high priority level to evaluate Short Term CR performances.

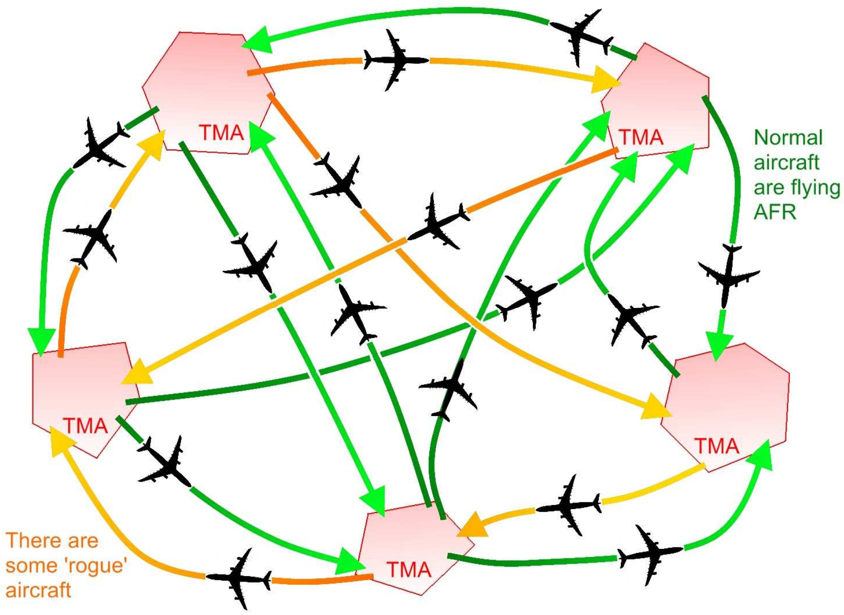


Figure I - 10 Rogue Aircraft Scenario

The questions to be addressed by this operational scenario are:

- How does the Loss of Separation rate relate to the percentage of non-self separating aircraft? Loss of Separation in this scenario might happen due to:
    - Aircraft which are self separating cannot cope with the number of aircraft which are disregarding conflicts.
    - Above a certain ratio, aircraft that disregard conflicts will start to encounter each other and produce unresolved conflicts. How often this happens at a given traffic density will provide a measure of the effects caused by some A[3] ConOps elements like:
        - The reduction of the SM to 3 NM horizontal and 900 ft vertical
        - Letting go of the ATM airspace structure (flight levels and airways)

- Self separation aircraft behaviour in the presence of non-self separation aircraft, in terms of CR algorithm performances. Both Medium Term and Short Term CR algorithms can be evaluated. The Medium Term CR can be evaluated by giving the non-self separating aircraft the highest priority. The Short Term CD can be evaluated by giving aircraft which are not resolving conflicts the lowest priority (so other aircraft will not react in Medium Term) and allow the conflicts to reach the short term.

- Interaction between rogue aircraft and non-normal or emergency aircraft can be assessed by adding non-normal aircraft to the scenario.

All the variables to be evaluated and the A^3 functionalities and assumptions made are the same as those for the baseline operational scenario.

I.5 Reduced Performance Scenarios

I.5.1 Reduced air-air communication range Scenario

In this scenario, using the Baseline Operational Scenario as a starting point, air-air communication range will (in a certain area of the airspace) be reduced as a result of weather interferences.

To obtain information about traffic outside Air-Air DL range, aircraft will rely on SWIM; however, in a situation like this the requirements placed upon this system's bandwidth, in order to be able to broadcast more information than normally, will be greater. Furthermore, the quality and update rate of traffic trajectory information will also be reduced from normal levels.

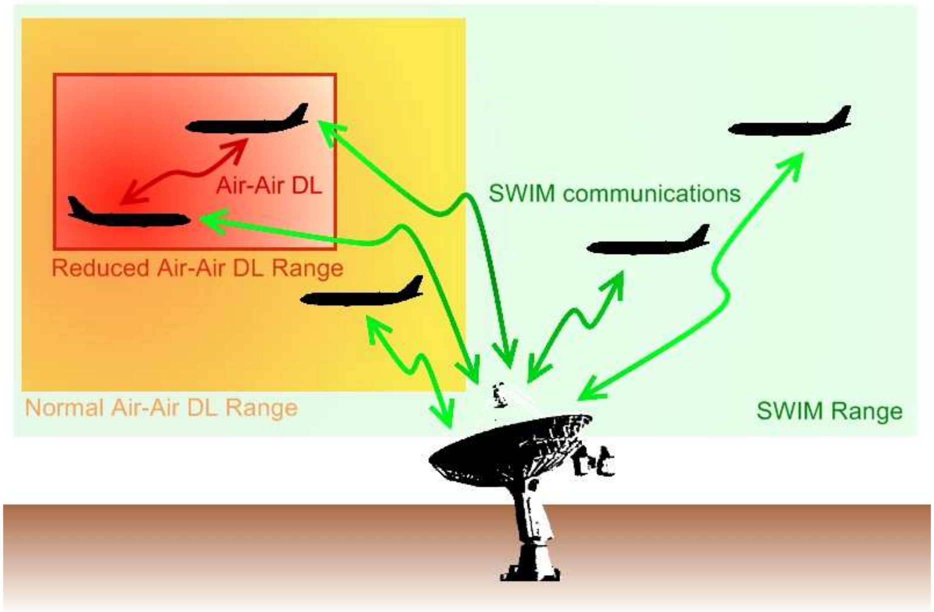


Figure I - 11 Reduced air-air communication range Scenario

The following aspects may be investigated:

- SWIM capabilities needed to support aircraft in this scenario.

- Impact of reduced quality in aircraft trajectory information (specially in terms of trajectory update rate) on ASAS performance.

I.5.2 Loss of long/medium term information Scenario

This scenario assumes aircraft are not receiving long term traffic and area information. Aircraft will only be aware of traffic inside Air-Air DL range. Other medium term ground functions may still be regarded operative. The loss of long term information will imply degradations in the following aspects:

- Flight crew situational awareness.
- Conflict Detection performances.
- Restrictions placed upon CR algorithms due to the lack of reliable longer term information.
- Flight crew decision-taking and manoeuvre execution time.
- Quality and update rate of traffic trajectory information.

The problem is furthermore complicated by the lack of consistency in situational awareness that will arise; traffic inside air-air communication range will still be broadcasting their full intent information, providing reliable information up to the 15 – 20 minutes time frame, while trajectory information for traffic just outside Air-Air DL range may not be available.

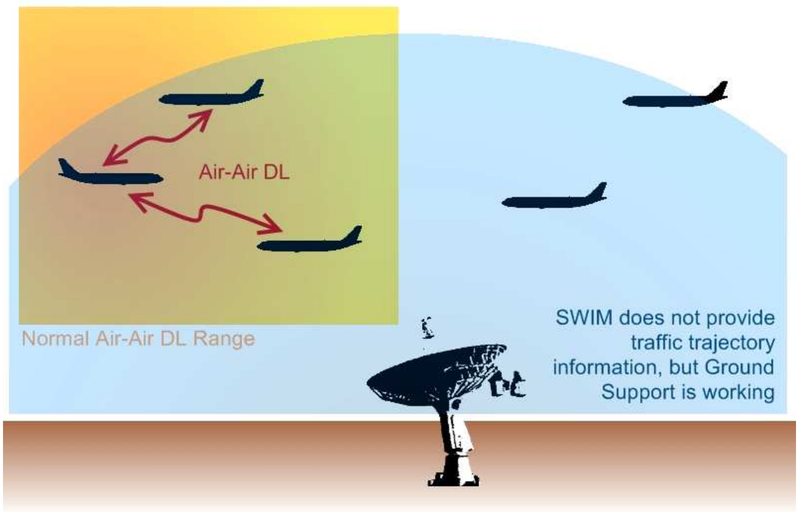


Figure I - 12 Loss of long term information Scenario

This scenario, together with the 'Reduced air-air communication range Scenario', can be useful to:

- Evaluate the relative performances of Air-Air DL and SWIM.
- Assess CD&R performance when fed with different kinds of traffic trajectory information.
- Evaluate flight crew workload levels in different conditions.

I.5.3 Diminished Ground Support Scenario

In order to evaluate the relative importance to the overall ATM system of the envisioned A^3 ConOps Ground Support functionalities, this scenario will hypothesize a reduction in ground support functionalities. This will impose constraints with a varying degree of severity upon the following aspects:

- Complexity and congestion prediction
- Long term areas information
- MTAZ aircraft presence
- CTA/RTA data information
- FOC data support
- Weather services

The use of radio communications to substitute data link for vital information (e.g. CTA/RTA) can be implemented, although reduced performances should be expected.

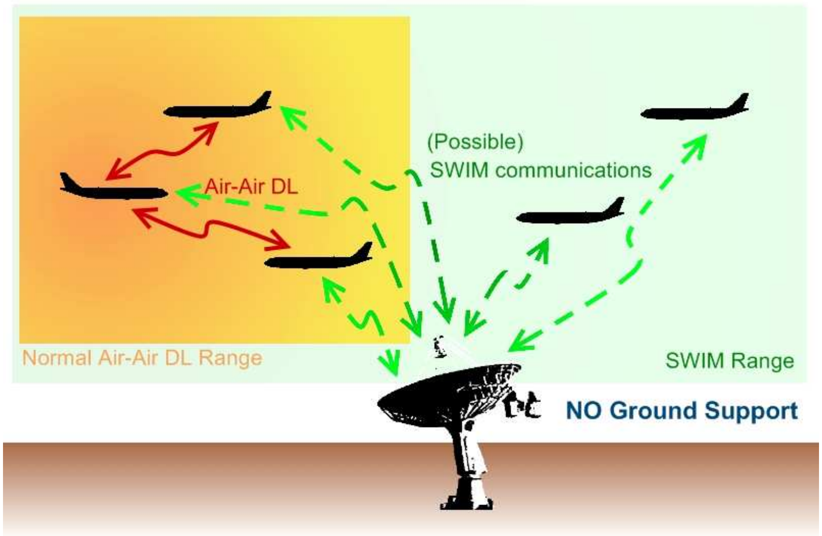


Figure I - 13 Diminished Ground Support Scenario

The following aspects should be analyzed:

- Impact on flow management and TMA arrival timing.
- Appearance of overly complex and congested areas due to limited aircraft trajectory management.
- CTA/RTA compliance.

All the variables to be evaluated and the A^3 functionalities and assumptions made, except for those involving Ground Support, are the same as those for the baseline operational scenario.

II Relationships with strategy programs

The following sources were used for considering the global strategic context of the A^3 Concept of Operations:

- Concept of Operations:
    - ICAO Doc 9854: Global Air Traffic Management Operational Concept (2005)
    - NextGen: Concept of Operations for the Next Generation Air Transportation System (ver. 2.0 – 13 June 2007)
    - SESAR D3: The ATM Target Concept (September 2007)
    - FAA/EUROCONTROL Cooperative R&D, Action Plan 23: *The Operational Role of Airborne Surveillance in Separating Traffic*, (version 0.1, December 2007)

- Implementation/Deployment Plans:
    - SESAR D4: The ATM Deployment Sequence (January 2008)
    - SESAR D5: Master Plan (April 2008)
    - NextGen: Integrated Work Plan (ver. 0.2 – 15 February 2008)

II.1 SESAR

The SESAR description provided in this Appendix is based on the adapted text from the main deliverables:

- D1, Air Transport Framework The Current Situation
- D2, The Performance Target
- D3, The ATM Target Concept
- D4, The Deployment Sequence
- D5, SESAR Master Plan
- D6, Work Programme for 2008-2013 (not considered here).

SESAR follows the performance-based approach as stated in ICAO Global Performance Manual. In this context, D2 (The Performance Target) set performance expectations which the ATM industry should deliver and established a SESAR performance framework based upon the 11 ICAO Key Performance Areas (shown in Figure II - 1), setting performance objectives for each of them, with associated indicators and targets. Summary of these 2020 Performance Targets is shown in Table II - 1 and Table II - 2.

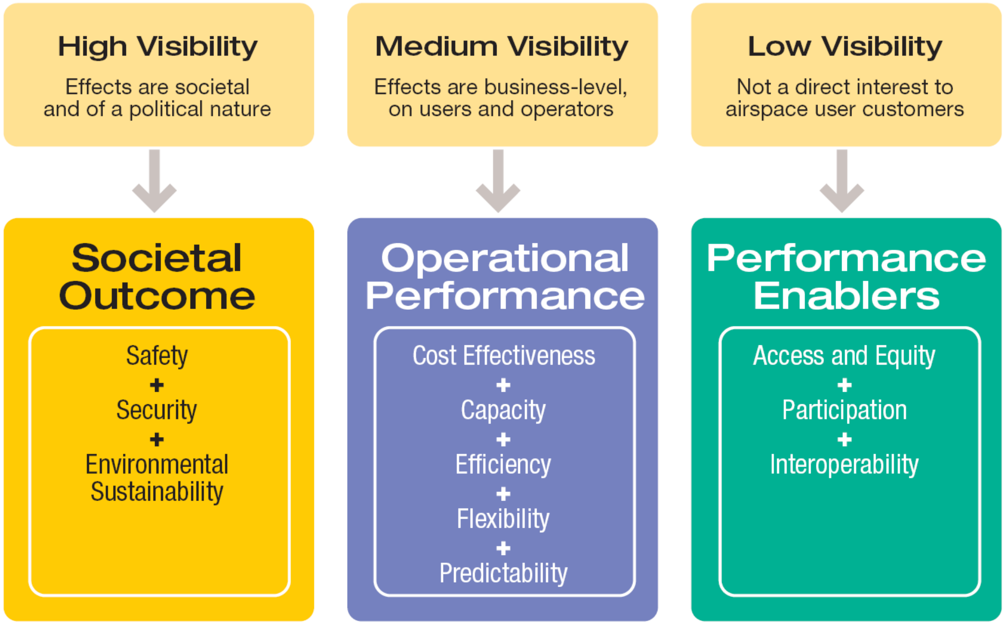


Figure II - 1 11 ICAO Key Performance Areas (KPAs) (SESAR D2)

In response to the performance objectives and targets, D3 has defined the Target Concept (shortly described within the Chapter 3) and D4 has outlined the overall deployment sequence for implementing it.

KPA	Key Performance Indicator (KPI)	Baseline		2020 Target	
		Year	Value	Absolute	Relative
Capacity	Annual IFR flights in Europe	2005	9.2 M	16 M	+ 73%
	Daily IFR flights in Europe	2005	29,000	50,000	+ 73%
	Best In Class (BIC) declared airport capacity in VMC (1 RWY), mov/hr	2008	50	60	+20%
	BIC declared airport capacity in VMC (2 parallel dependent RWYs), mov/hr	2008	90	90	+0%
	BIC declared airport capacity in VMC (2 parallel independent RWYs), mov/hr	2008	90	120	+25%
	BIC declared airport capacity in IMC (1 RWY), mov/hr	2008	25	48	+90%
	BIC declared airport capacity in IMC (2 parallel dependent RWYs), mov/hr	2008	45	72	+60%
	BIC declared airport capacity in IMC (2 parallel independent RWYs), mov/hr	2008	45	96	+110%
Cost Effectiveness	Total annual en-route and terminal ANS cost in Europe, €/flight	2004	800	400	-50%
Efficiency	Scheduled flights departing on time (as planned)			>98%	
	Avg delay of the remaining scheduled flights			<10 min	
	Flights with block-to-block time as planned			>95%	
	Avg. block-to-block time extension of the remaining flights			<10 min	
	Flights with fuel consumption as planned			>95%	
	Avg. additional fuel consumption of the remaining flights			<5%	
Flexibility	Accommodation of VFR-IFR change requests			>98%	
	Unscheduled flights departing on time (as requested)			>98%	
	Avg delay of the remaining unscheduled flights			<5 min	
	Scheduled flights with departure time as requested (after change request)			>98%	
	Avg delay of the remaining scheduled flights			<5 min	

Table II - 1 Summary of the 2020 Performance Targets – Part I (SESAR D5)

KPA	Key Performance Indicator (KPI)	Baseline Year	Baseline Value	2020 Target Absolute	2020 Target Relative
Predictability	Coefficient of variation for actual block-to-block times: for repeatedly flown routes			<1.5%	
	Flights arriving on time (as planned)			>95%	
	Avg arrival delay of the remaining flights			<10 min	
	Total reactionary delay	2010			-50%
	Reactionary flight cancellation rate	2010			-50%
	Total service disruption delay	2010			-50%
	Percentage of diversions caused by service disruption	2010			-50%
Safety	Annual European-wide absolute number of ATM induced accidents and serious or risk bearing incidents	2005		No increase	
	Safety level (per flight)	2005			x 3
Environmental Sustainability	Avg. fuel savings per flight as a result of ATM improvements	2005			10%
	Avg. CO_2 emission per flight as a result of ATM improvements	2005			-10%
	Compliance with local environmental rules			100%	
	Number of proposed environmentally related ATM constraints subjected to a transparent assessment with an environment and socio-economic scope			100%	

Table II - 2 Summary of the 2020 Performance Targets –Part II (SESAR D5)

Within the D4, the Target Concept of Operations was organized into so-called Lines of Change (LoC) describing the main areas and directions of essential progress to be made. The list and short description of these LoC is provided in Table II - 3.4 and Table II - 4.

Name	Description	Main ConOps Aspects covered
Information Management	All aspects of creating, sharing, obtaining, providing, protecting and using information.	Basic and essential support for all aspects of the ConOps. Support to CDM
Moving from airspace to trajectory based operations	All aspects related to trajectory based operations including the steps required to move from the airspace based to the trajectory-based concept. Includes all aspects related to operations that continue to be airspace based (e.g. military).	Airspace categories. Trajectory based operations. User preferred routing environment. Enhanced integration of diverse airspace use. Access and equity. Minimising segregation.
Collaborative planning using the Network Operations Planner	All aspects related to the initiation, development, refinement, sharing and updating of the Business/Mission Trajectories and all aspects related to the development and use of the NOPLA. Also includes all aspects related to the creation of the NOP using NOPLA. Includes also longer term resource planning. Includes all aspects related to the sharing of flight data, processing of incoming and generation of outgoing ICAO E-FPL. Includes user preferred routing.	Collaborative planning. Trajectory based operations. Network Operations Plan and related applications. Trajectory sharing. Flight data input. All planning horizons. Airport planning
Managing the Network	All aspects related to the development and management of the ATM network, including the provision of the necessary resources to cater for demand Includes all aspects related to automated configuration tools. Includes free route operations (network aspects).	Regional and Sub-regional network management. Demand and capacity balancing

Table II - 3 Lines of Change (LoCs) of the SESAR Target Concept – Part I (SESAR D4)

Name	Description	Main ConOps Aspects covered
Managing Business Trajectories (Military Mission Trajectories) in real time.	All aspects related to the execution of user or ATM originated changes to the trajectory actually being flown (for conflict management, implementing queue management constraints, avoiding weather or restricted areas, etc.).	Managing/implementing constraints. Trajectory management requirements. ATC coordination using shared trajectories. Complexity management
Cooperative ground and airborne decision making tools.	All aspects related to decision-making auto-mation (e.g. ground based conflict detection and resolution, what-if, ASAS conflict probe, etc.)	Controller and pilot automation tools
Queue management tools	All aspects related to tools used to set up and manage queues (except for implementing the results, see 5 above). Includes UDPP.	Arrival and departure management. UDPP.
New separation modes	All aspects related to realising the various ANSP and airborne separation modes.	ANSP modes. Airborne modes. Mixed mode opera-tions.
Improved cooperative ground and airborne safety nets.	All aspects related to advanced STCA and ACAS. Includes the management of variable separation minima.	Collision avoidance.
Airport throughput, Safety and Environment	All aspects related to airport throughput from terminal operations through final, ground movement and turn round as well as departure until established on departure route. Also includes all aspects related to airside safety.	Spacing on final. Runway operations. Taxi guidance and operations. Runway safety.

Table II - 4 Lines of Change (LoCs) of the SESAR Target Concept – Part II (SESAR D4)

Along each LoC the specific and detailed changes required to transition from today's system (called "Operational Improvements (OI) steps") where defined together with the corresponding time frame.

In the Master Plan (D5), the OIs have been further structured in a series of ATM Service Levels (0-5) and organized in Implementation Packages (IP) 1-3 depending upon the date at which the corresponding capability can become operational (Initial Operational Capability (IOC) date):

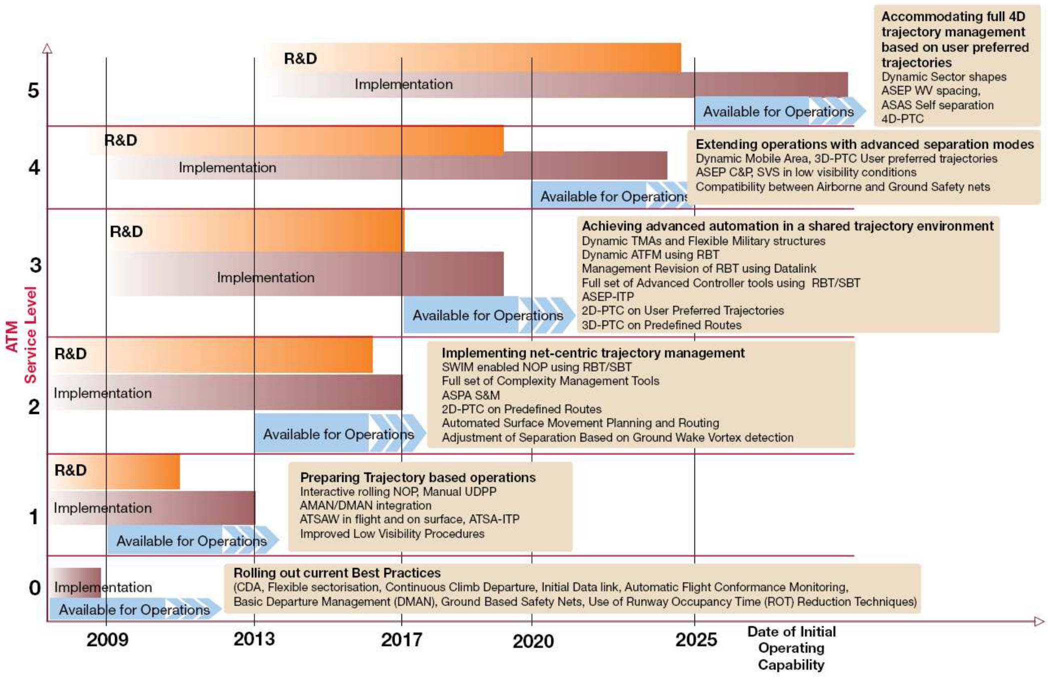
- IP1 – Implementation Package 1 (short-term: IOC dates up to 2012)
  - Covers ATM Service Levels 0 and 1
- IP2 – Implementation Package 2 (medium term: IOC dates in the period 2013-2019)
  - Covers ATM Service Levels 2 and 3
- IP3 – Implementation Package 3 (long term: IOC dates from 2020 onwards)
  - Covers ATM Service Level 4 and 5

The list of OI Steps within the LoC#8 (New Separation Modes) is given in Table II - 5.

Line of Change Code	OI step Code	OI Step Title	Operating Context	IP	Service Enhancement Transition Steps
L08	CM-0501	4D-PTC for Equipped Aircraft with Extended Clearance 4D-PTC	En-Route	IP3	SETS3-c
L08	CM-0601	Precision Trajectory Clearances (PTC)-2D Based On Pre-defined 2D Routes	TMA, En-Route	IP2	SETS2-c SETS2-d
L08	CM-0602	Precision Trajectory Clearances (PTC)-3D Based On Pre-defined 3D Routes	TMA, En-Route	IP2	SETS2-c SETS2-d
L08	CM-0603	Precision Trajectory Clearances (PTC)-2D On User Preferred Trajectories	TMA, En-Route	IP2	SETS2-c SETS2-d
L08	CM-0604	Precision Trajectory Clearances (PTC)-3D On User Preferred Trajectories (Dynamically applied 3D routes/profiles)	TMA, En-Route	IP3	SETS3-c SETS3-d
L08	AUO-0401	Air Traffic Situational Awareness (ATSAW) on the Airport Surface	APT	IP1	SETS1-e
L08	AUO-0402	Air Traffic Situational Awareness (ATSAW) during Flight Operations	TMA, En-Route	IP1	SETS1-c SETS1-d
L08	AUO-0503	In-trail Procedure in Oceanic Airspace (ATSA-ITP)	En-Route	IP1	SETS1-c
L08	CM-0701	Ad Hoc Delegation of Separation to Flight Deck - In Trail Procedure (ASEP-ITP)	En-Route	IP2	SETS2-c
L08	CM-0702	Ad Hoc Delegation of Separation to Flight Deck - Crossing and Passing (C&P)	En-Route	IP3	SETS3-c
L08	TS-0105	ASAS Sequencing and Merging as Contribution to Traffic Synchronisation in TMA (ASPA-S&M)	TMA	IP2	SETS2-d
L08	TS-0107	ASAS Manually Controlled Sequencing and Merging	TMA	IP1	SETS1-d
L08	AUO-0504	Self-Adjustment of Spacing Depending on Wake Vortices	APT, TMA	IP3	SETS3-d SETS3-e
L08	CM-0704	Self Separation in Mixed Mode	En-Route	IP3	SETS3-c

Table II - 5 OI Steps in LoC#8 – New Separation Modes (SESAR D4)

The SESAR Master Plan outline of the anticipated IOC dates for various ATM Service Levels and of their high-level description is shown in Figure II - 2.



Note: Long R&D and implementation durations are the result of combining many data but do not reflect the time needed to introduce a specific improvement at a specific location.

Figure II - 2 SESAR Master Plan Overview (SESAR D5)

As shown in Figure II - 2, the airborne self separation is included in Service Level 5 within the Implementation Package 3 (beyond 2020). The anticipated ATM changes related to the Service Level 5 are shown in Table II - 6.

LoC#2–Moving from Airspace to Trajectory Based Operations
Dynamic Sector shapes: ATC sector shapes and volumes are adapted in real-time to respond to dynamic changes in traffic patterns and/or short-term changes in users' intentions.
R&D
Elaborate the concepts of Dynamic Sectors and Dynamic TMAs in respect of: the operational contexts (airspace, complexity level, traffic mix…) in which they apply. Assess the integration and impact on capacity planning, DCB/ASM, scenario management and flight planning processes.
LoC#8–New Separation Mode
ASEP WV spacing: Deploy Self-Adjustment of spacing depending on Wake Vortices. The spacing is adjusted dynamically by the pilot based on the actual position of the vortex of the predecessor.
Self-separation: Deploy the delegation of the separation by the controller between an aircraft and all the other aircraft in mixed-mode environment through new air broadcast and reception of trajectory data and new onboard conflict detection and resolution functions.
4D-PTC: Deploy the 4D-PTC using longitudinal navigation performance management from the aircraft.
R&D
Elaborate the concepts of A/A services, including exchange of weather hazards and Wake-Vortexes information. Develop and validate 4D-PTC with extended clearance. This should identify the trajectory management requirements and the separation minima applicable to 4D-PTC with extended clearance and should take into account the improved RNP capability of aircraft. Compare alternative means of separation management like airborne self management; cooperative self-separation for business jet in low density high altitude airspace (e.g. above FL410) should be started as early as possible to validate the self-separation concept. Investigate potential Human Factor impact of the mixed mode operation on both pilots and controllers.

Table II - 6 Service Level 5 required changes (SESAR D5)

According to D4, it is anticipated that within the Implementation Package 3:

- Uncertainty of trajectory prediction is reduced by the implementation of the Trajectory Management Requirements.
- There is an implementation of SWIM full service.
- There is an implementation of air-air services (either through a second ADS-B link or through a significant enhancement of the existing one).
- Only 2 categories of airspace exist: managed and unmanaged.
- Free routing will be in place except TMA.
- Dynamically shaped airspace and terminal area is in use.
- 3D Precision Trajectory Clearances is implemented.
- Adjustment of spacing based on airborne wake vortex detection is implemented.

II.2 NextGen

The ASAS self separation notion within NextGen is nearly the same as in SESAR and also the implementation timeframe is very similar. The earliest implementation of self separation is expected in oceanic and remote airspace, probably with separation standards between current procedural standards and actual radar-based standards.

The anticipated global NextGen airspace structure is shown in Figure II - 3.

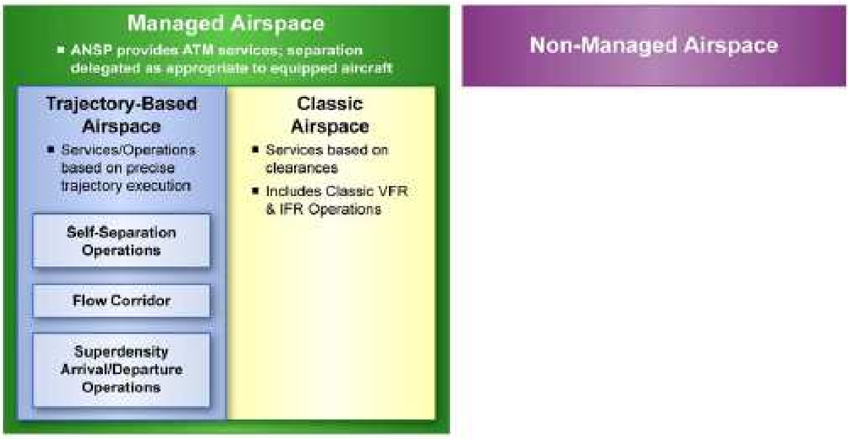


Figure II - 3 NextGen airspace Structure Overview (NextGen ConOps)

In addition to the factors contained in the SESAR, NextGen introduces the concept of so-called “flow corridors” for the super dense traffic conditions typically experienced in the terminal areas:

“When demand is very high, the ANSP may implement “flow corridors” for large numbers of separation-capable aircraft travelling in the same direction on very similar routes (see Figure II - 4). Flow corridors consist of long tubes or “bundles” of near-parallel 4DT assignments, which consequently achieve a very high traffic throughput, while allowing traffic to shift as necessary to enable more effective weather avoidance, reduce congestion, and meet defence and security requirements. The airspace for aircraft operating in flow corridors is protected; aircraft not part of the flow do not penetrate the corridor”.

It is anticipated that the airborne self separation will be used also within these corridors.

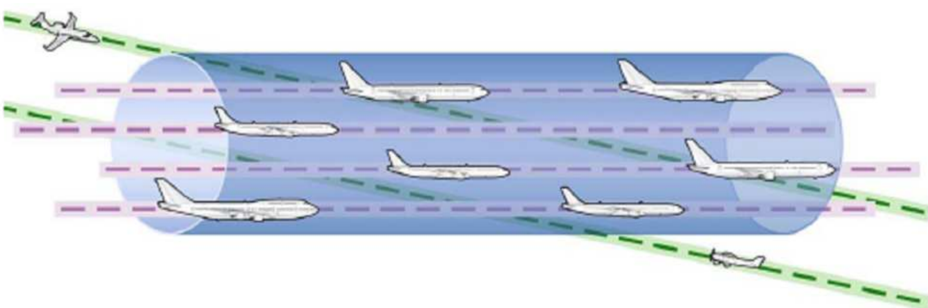


Figure II - 4 NextGen Flow Corridors (NextGen ConOps)

Considering the deployment/implementation plans, the NextGen Separation Management Operation Improvement roadmap is shown in Figure II - 5.

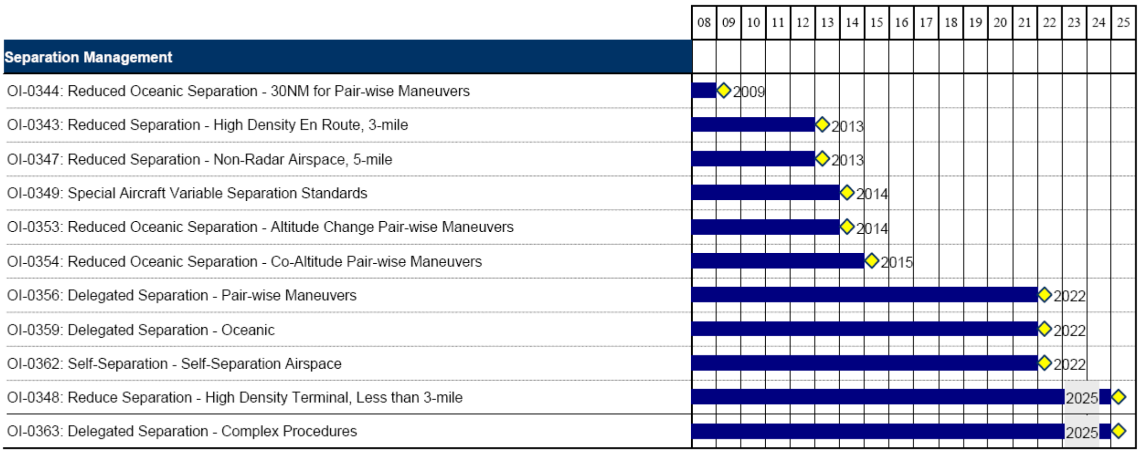


Figure II - 5 Separation Management Operational Improvement Roadmap (NextGen Integrated Work Plan)

III Relation to other research

III.1 Summary of the state of the art

The A^3 ConOps is an autonomous aircraft operational concept, but this is just one aspect among many that are currently being investigated in the Airborne Separation Assistance Systems (ASAS) quickly developing field. The following sections present a concise picture of the state of the art in the ASAS world when regarding both conceptual developments in self separation (under the title 'Self separation principles of operation') and developing applications (under the title 'ASAS applications assessment'), with the aim of providing the reader a quick review of the ASAS R&D initiatives.

III.1.1 Self separation principles of operation

The document '***Principles of Operation for the use of Airborne Separation Assurance Systems'***[30] elaborated by the FAA/EUROCONTROL R&D Committee, developed the principles of operation for airborne self separation applications. This chapter's text has been extracted and adapted from this document.

III.1.1.1 ASAS categories

Four ASAS categories are defined:

- ***Airborne traffic situational awareness*** is aimed at enhancing the flight crews' knowledge of the surrounding traffic situation.
- ***Airborne spacing,*** which requires the flight crews to achieve and maintain a given spacing with designated aircraft, as specified in a new ATC instruction.
- ***Airborne separation,*** where the controller delegates separation responsibility and transfers the corresponding separation tasks to the flight crew, who ensures that the applicable airborne separation minima are met.
- ***Airborne self separation,*** which requires flight crews to separate their flight from all surrounding traffic, in accordance with the applicable airborne separation standards and rules of flight.

III.1.1.2 Airborne self separation applications

Typical Airborne Self separation applications include:

- ***Airborne self separation in ATC-controlled airspace:*** a controller can delegate full responsibility for self separation to the flight deck of suitably equipped aircraft through a new clearance.

[30] PO-ASAS v7.1 (released 19/06/2001) http://adsb.tc.faa.gov/RFG/po-asas71.pdf

- ***Airborne self separation in segregated en-route airspace:*** this application requires the flight crews to self-separate from other traffic inside that airspace without ATC support.

- ***Airborne self separation in mixed-equipage en-route airspace:*** while in the en-route airspace, appropriately equipped aircraft (referred to as "autonomous aircraft") are given the authority, capability, and procedures needed to execute user-preferred trajectory changes without requesting ATS provider clearance to do so.

III.1.2 ASAS Applications assessment

This appendix presents a table showing the typology of ASAS applications. Within ASAS-TN2 WP3 '***ASAS application maturity assessment***'[31] (March, 2008), several ADS-B applications were grouped in five categories depending on whether they could be characterised as ADS-B surveillance or by the four ASAS categories. The applications per category are as follows:

CATEGORY	APPLICATIONS
ADS-B surveillance	Airport surface surveillance (ADS-B-APT)
	ATC surveillance in radar airspace (ADS-B-RAD)
	ATC surveillance in non-radar areas (ADS-B-NRA)
	Aircraft derived data for ground tools (ADS-B-ADD)
Airborne traffic situational awareness	Enhanced traffic situational awareness during flight operations (ATSA-AIRB)
	Enhanced traffic situational awareness on the airport surface (ATSA-SURF)
	In-trail procedure in procedural airspace (ATSA-ITP)
	Enhanced visual separation on approach (ATSA-VSA)
Airborne spacing	Sequencing and merging operations (ASPA-S&M)
	Enhanced crossing and passing operations (ASPA-C&P)
Airborne Separation	Lateral crossing and passing (ASEP-LC&P)
	Vertical crossing and passing (ASEP-VC&P)
	In-trail procedure (ASEP-ITP)
	In-trail follow (ASEP-ITF)
	Sequencing and merging operations (ASEP-S&M)
	In-trail Merge (ASEP-ITM)
Airborne Self separation	Self separation in segregated free flight airspace (SSEP-FFAS)
	Self separation in managed airspace (SSEP-MAS)
	Self separation in an organised track system (SSEP-FFT)

III.2 Previous research projects

In the previous iFly's deliverable D1.1 '*Autonomous Aircraft Advanced (A^3) High Level ConOps*', in order to select the most interesting inputs or candidate elements of the concept among a large list of projects proposed from the previous state-of-the-art aeronautics research results and be able to define a "baseline" operational High Level concept and alternatives, common criteria among all partners involved were defined. It was agreed that useful projects should include references to the following key words or questions:

[31] Document Ref: ASAS-TN2/WP3/Report/3.0, http://www.asas-tn.org/reports

a. Autonomous Aircraft
b. Conflict Prediction
c. Separation Minima
d. Complexity Prediction (Clustering)
e. Free Flight procedures and implementation options, i.e. conflict resolution based on priority rules or on co-operative actions, level of coordination between aircraft, etc.
f. Conflict Resolution: ASAS (Airborne Separation Assistance System), ACAS (Airborne Collision Avoidance System), etc.
g. ASAS-TCAS (Traffic Alert and Collision Avoidance System) interaction
h. Conflict resolution algorithms, i.e. solving multiple conflicts one by one or according to a full concurrent way
i. Distribution of Conflict Resolution responsibility (automation/human, ground/air)
j. Human factors and goal settings of pilots and of airlines
k. Identification of elements such as pilots flying/non-flying, systems components and entities (like the aircraft's position evolution and the Conflict Management Support systems), air traffic controller, global navigation and surveillance equipment (like the communication frequencies and the satellite system), etc.
l. Current and future technological issues, equipment performance and airborne requirements for Free Flight: air-ground communication (e.g. TIS-B), air-air communication, systems, displays, etc. Focused on functionalities more than on the description of the technology
m. Merging and Spacing
n. Free Flight Airspace (FFAS), Free Route Airspace and Restrictions for Free Flight on European airspace
o. Airspace Division
p. Risk & Safety Assessment as a function of traffic density increase. Does the selected project/paper tackle the Free Flight risk assessments weaknesses detected?
q. Benefits & Cost Assessment, impact on economy caused by organisational and institutional issues derived of the introduction of the autonomous aircraft advanced operations en-route
r. Overall Air Traffic ConOps

Taking into account this agreed set of topics relevant to the ConOps, the iFly team built a repository of existing research and technology projects as a working matrix to offer an overview of the projects identified. A project was considered as a relevant input if it:

- Was able to introduce something new about the topics listed in the agreed common criteria, or

- Offered an evaluation of some methods already developed.

The following list is a reduction of the work presented in Deliverable D1.1, where only those projects which have been considered relevant to the issues presented in the ConOps are considered. The following table shows the list of the projects selected:

3FMS	Free Flight – Flight Management System
AATT	Advanced Air Transportation Technologies
ARTAS	ATM suRveillance Tracker And Server

CARE-ASAS	Co-operative Actions of R&D in EUROCONTROL / Airborne Separation Assistance System
DAG-TM CE5	Distributed Air/Ground Traffic Management Concept Element 5 : En-route Free Maneuvering for User-Preferred Separation Assurance and Local TFM Conformance
EMERTA	Emerging Technologies and Opportunities for ATM
ERASMUS	En-route Air Traffic Soft Management Ultimate System
FACES	Free flight Autonomous and Coordinated Embarked Solver
FALBALA	First Assessment of the operational Limitations, Benefits & Applicability for a List of package I AS applications
FlySAFE	- No extended title -
FRAP	Free Route Airspace Project
FREER	Free-Route Experimental Encounter Resolution
HYBRIDGE	Distributed Control and Stochastic Analysis of Hybrid Systems Supporting Safety Critical Real-Time Systems Design
IAPA	Implications on Airborne Collision Avoidance System (ACAS) Performances due to Airborne Separation Assistance System (ASAS) implementation
INTENT	The Transition towards Global Air and Ground Collaboration In Traffic Separation Assurance
MA-AFAS	More Autonomous Aircraft in the Future ATM System
MFF	Mediterranean Free Flight Programme
NEAN	North European ADS-B Network
NEAP	North European CNS/ATM Application Project
NUP	NEAN Update Programme
RESET	Reduced Separation Minima
Safe Flight 21	- No extended title -

A brief description of each of these projects follows, showcasing the key areas of interest to iFly and, more specifically, to the A^3 ConOps.

3FMS

The objective of the 3FMS project is to prepare an early functional definition of the European Flight Management System for free-flight operation. The main expected 3FMS achievements are the definition of the Free Flight functions compliant with the new AIRBUS FMS, their evaluation and demonstration in an AIRBUS flight simulator and a list of recommendations for their implementation in the future European ATM system. As a baseline to be reviewed in the course of the project, the on-board tactical flight management functions are aircraft separation, anticipatory terrain avoidance, weather management, and route of preference. The 3FMS technical approach will follow a classical R&D life-cycle: definition, design and prototyping, development, integration, functional validation and operational evaluation.

This project aimed to provide new capabilities, such as separation assistance algorithms, and aimed to further develop existing capabilities such as terrain and weather databases. The simulation of technologies such as ADS-B, CPDLC and advanced Human Machine Interfaces (HMIs) were used to provide useful indications of the required performance of these technologies.

AATT

The AATT Project was completed on September 30, 2004. The major focus of the AATT Project was to improve the capacity of transport aircraft operations at and between major airports in the National Airspace System (NAS) by developing decision support tools and concepts to help air traffic controllers, airline dispatchers, and pilots improve the air traffic management and control process from gate-to-gate. AATT addressed some of the most difficult air traffic management issues, including operations in complex airspace and the implementation of distributed air/ground responsibilities for separation.

Technologies developed in the Project include terminal/transition/en-route airspace tools for arrival, surface, and departure operations; and flight deck and ground-based tools to support free flight concepts.

ARTAS

It calculates an overall radar image on the basis of position references provided by several radar inputs. ARTAS enables the radar displays used by skyguide's air traffic controllers to be renewed every 4 seconds.

The new concept of free flight will require from each aircraft overlying the intended airspace to be "updated with the most accurate picture" of the surrounding traffic, as well as an anticipated awareness of the approaching aircraft vectors. This "accurate" picture, based on processed radar data reports to form a best estimate of the current Air Traffic situation, is provided to all Users interested in air traffic.

CARE-ASAS

Although CARE-ASAS was conducting R&D activities related to ASAS, it could not be considered as an R&D project on ASAS. The main goal of CARE-ASAS was to help the organisations working on ASAS R&D to speak the same language and to work together. It provides general considerations for airborne self separation as well as widely accepted terminology. The project was concluded in 2004.

It also defines principles of operation for different categories of ASAS application.

DAG-TM CE5

DAG-TM (Distributed Air/Ground Traffic Management) is a NASA concept for gate-to-gate operations beyond the year 2015. It will address dynamic constraints such as bad weather, Special Use Airspace and arrival metering/spacing. Out of a total of 15 concept elements, 4 have been selected for initial studies. The so-called Concept Element 5 is called '*En-route Free Maneuvering for User-Preferred Separation Assurance and Local TFM Conformance*', and its major purpose is to distribute the separation assurance and tactical traffic management functions to the flight crew.

A fully developed concept of operations that is based upon a similar philosophy than that of the A^3 ConOps, it is a major reference for any works undertaken in the field of ASAS and self separation.

EMERTA

The objectives of this project are:

- To establish the feasibility of using emerging NGSS services 'as they are' to meet Air Traffic Service (ATS) and Airline Operation Centre (FOC) requirements. This will include the definition of a European-level NGSS demonstration/validation project.
- To support a European input to international standardisation activities in such forums as ICAO and RTCA/EUROCAE, insofar as they are concerned with the technologies and concepts covered by Project EMERTA.
- To provide inputs to the specification of detailed requirements for a second generation of Low/Medium Earth Orbit (LEO/MEO) satellite systems and services, for deployment beyond the year 2005.
- To assess the practical feasibility of the early introduction, in the European ATM environment, of one or more selected ADS-B/ASAS application scenarios, paying particular attention to safety and transition aspects. This will be supported by an outline indication of the cost/benefit issues associated with the scenario(s).
- To develop initial indications and guidelines on how to deploy ADS-B in Europe, in the context of the ASAS concept, in terms of the potential requirement for reserved airspace and how best to deal with a mixed aircraft population (where some aircraft have an ASAS capability, but others do not).

ERASMUS

The aim of ERASMUS is to improve the split of responsibility between humans and machines, ensuring that while for safety reasons humans retain ultimate control, machines can take on an increasing number of tasks.

ERASMUS proposes to open a new approach of ATM automation and will make proposals in three specific applications ranging from low levels of automation where the computer acts as an advisor to the controller to much more developed levels of automation where the computer acts in a subliminal way on behalf of the controller. As a first step, it will examine how to increase trajectory prediction strengthening the use of existing air/ground data-link facilities while at the same time incorporate the cognitive logic of air traffic controllers into existent Medium Term Conflict Detection systems . Then, it will make proposals on how to reduce the traffic complexity by developing ‘subliminal’ problem resolution actions (minor speed regulation not perceivable by the Air traffic controller) to be performed by the machine. It is assumed that reducing the traffic complexity would release some of the Air Traffic controller cognitive resource which would be used to perform other tasks, or to manage more aircraft

FACES

FACES is an autonomous and coordinated embarked (on board) conflict solver for Free Flight airspace. It solves conflict by computing simple manoeuvres that guarantees conflict free trajectories for the next 5 minutes (min). Coordination is ensured by giving sequential manoeuvres to aircraft with a token allocation strategy. FACES can be implemented with the current positioning, broadcasting and flight management technology. Moreover, it is robust to communication or system failure for time up to one or two minutes.

The project introduces a distributed algorithm, which provides an order of priority for aircraft in a cluster. A one against many algorithm is then applied in the given order.

FALBALA

The project brings elements for consideration by the future CDTI (Cockpit Display of Traffic Information) designers. These elements should also help defining required performances of an Airborne Surveillance and Data Processing system in the European airspace. The analysis of the maximum numbers of visible aircraft has also demonstrated the need for traffic filtering on-board the aircraft.

FlySAFE

FlySAFE designs, develops, implements, tests and validates a complete Next Generation Integrated Surveillance System (NG ISS), going a generation further than the emerging integrated safety systems. The project is the "strategic" follow-on to the ISAWARE and ISAWARE II projects in which the emphasis was more on "terrain and traffic" information presentation to the pilot.

The 3 First-Level Objectives of FLYSAFE are:

1. To develop, validate and test an innovative, efficient and competitive on-board integrated surveillance system (NG ISS), based on European resources, and prove that it increases safety.
2. To develop, validate and test ground weather means (WIMSs) to provide aircraft with weather safety related information and prove that they increase safety.
3. To develop international standards to support the definition of the two systems (on-board and on-ground) above.

FRAP

The project is part of the organisation's strategy for improving airspace management for the year 2000 and beyond. FRAP is designed to offer aircraft operators direct routes through the upper airspace of eight European states from entry point to exit point without having to follow a fixed-route structure

FREER

Freer Flight (formally FREER) is the historic name of ASAS activities at EEC. It investigates the enhancement of air traffic services through a greater involvement of the flight crew and the aircraft systems in a tighter co-operation with controllers and the ATM systems through the introduction of new spacing instructions.

Since 2002, the project has been (re)named CoSpace, and is now in the SSP (Sector Safety and Productivity) business area. The objective of the CoSpace project is to determine the operational feasibility and potential benefits of the use of spacing instructions ("airborne spacing"). The CoSpace project covers concept definition up to validation aspects through human-in-the-loop and model-based simulations.

HYBRIDGE

It has developed innovative approaches to handling uncertainty in air traffic management. iFly can be considered a follow-on to the Hybridge project.

At the end of (and following) Hybridge an autonomous aircraft concept (AMFF) was assessed [Web Ref. 3].

IAPA

It investigates the potential issue of airborne collision avoidance system (ACAS) and airborne separation assistance system (ASAS) interaction in the ECAC airspace. It is focused on identifying potential operational issues, and providing recommendations, related to the potential interaction between the ACAS logic and future ASAS application procedures. Phase I of the IAPA project is now completed: an initial, yet substantive, analysis of the potential ACAS / ASAS interaction issue was undertaken with an ASAS 'Package 1' application, and the framework has been established for an in-depth investigation within Phases II and III.

The recommendations of IAPA project about the ACAS / ASAS interaction should be respected.

- **The ACAS constraint must be taken into account when developing ASAS applications envisaged for implementation.**
    - In this perspective, the IAPA study should help in identifying potential ACAS / ASAS interaction issues and providing guidelines for the development of future ASAS applications.

- **Further in-depth analysis of the identified ACAS / ASAS interaction issues should be performed.**
    - The approach adopted within IAPA Phase II should well support this more in-depth investigation of the ACAS / ASAS interaction issue.
    - The performance of simulations based on different sources of data should compensate for the limitations related to any one of them, and to identify and assess a comprehensive set of issues.
    - The use of a common simulation framework during the various data-oriented studies should allow for the validation of the ACAS / ASAS interaction trends identified with each source of data.

- **The impact of ASAS operations on safety benefits provided by ACAS requires to be investigated.**
    - In this perspective, the safety case (based on the ED78A OSA methodology) to be conducted within IAPA Phase II from an ACAS perspective should well support this ACAS safety analysis during ASAS operations.

The IAPA methodology has proven successful in assessing the ACAS / ASAS interaction issue and would equally benefit to any future investigation of the interaction between ACAS and ATM changes in the provision of separation.

INTENT[32]

The research question of INTENT is "How does the level of aircraft INTENT information, shared among ATM users and actors, relate to the air traffic system capacity, the avionics design and ATM system design?". To answer this question, a relationship between aircraft intent information, the place of responsibility for the traffic separation assurance process and airspace capacity was investigated using compressed-time simulations containing human characteristics.

The results of this project show that Conflict Detection and Resolution (CD&R) tools including intent information for both controllers and airborne were found to have little or no significant result on workload, and thus on airspace, when compared to the airborne state-based reference. However, conflict detection and resolution systems based on intent information are preferred over state-based systems, both on the ground and in the air.

Fast-time simulations have shown that systems based on intent information are more efficient in terms of time, distance and fuel than systems based on only state information, both in ground and airborne concepts. This suggests that although exchanging aircraft intent information does not appear to increase airspace capacity, it might be very beneficial from a flight efficiency point of view.

The research suggested that, in the long term, ATM systems based on concepts where flight crews have the primary responsibility for separation are likely to offer several times the capacity of those based on ground control concepts.

A function analysis was performed for the CD&R function and the subsequent function allocation process identified three potential ATM systems: a ground-based system (all CD&R functions on the ground), an airborne system (all CD&R functions in the air) and a hybrid system (part of the CD&R functions on the ground, part in the air). From the function allocation process, it was concluded that there are two promising systems to look into further:

- Airborne system, because of the large capacity gains as found in the experiments
- Hybrid system, because of the expected more optimal and convergent overall solutions

Although promising, a list of issues was identified within the function allocation task regarding these two systems, such as human involvement / tasks, solution convergence, safety, certification and legal aspects. These issues should be further studied before (one of) these ATM systems can be implemented. Moreover, the hybrid system, which was not studied within INTENT, should be further studied in terms of potential capacity gains.

Finally, an implementation roadmap was derived for both the airborne and hybrid system. It was found that emphasis on the ground will be on the following systems for CD&R with intent information for the hybrid system:

[32] Final results adapted from INTENT D4.1, '***Project Executive summary***', INTENT_D4-1_v02_24-06-2003_P

- ADS-B receivers
- Controller-Pilot Datalink (CPDLC)
- Surveillance Data Processing (SDP)
- Flight Data Processing (FDP)
- Controller Working Position (CWP)
- Conflict Detection and Resolution (CD&R)

MA-AFAS

MA-AFAS developed and flew an advanced avionics system that supported Cockpit Display of Traffic Information, station keeping and autonomous crossing, sequencing and merging procedures.

MFF

Mediterranean Free Flight Programme studied innovative concepts based on a set of defined technical requirements designed to improve the management of air traffic in the Mediterranean area.

Between 2000 and 2005, MFF validation activities ranged from Free Routing techniques enabling user preferred trajectories to ASAS self separation (Free Flight) in which aircraft maintain their own separation from others in specially designated airspace [Ref. 13].

NEAN

Under this project, an ADS-B capability is being created through a network of ground stations and mobile VDL Mode 4 equipment that is being installed in commercial aircraft and airport vehicles.

NEAP

The overall project objectives were to investigate, specify, develop, test and evaluate civil aviation user applications and services within an integrated communications, navigation and surveillance (CNS) concept. Activities focused on the following domains:

- Enhanced surveillance for Air Traffic Control.

- Pilot situational awareness.

- GNSS (Global Navigation Satellite System) precision navigation capability for all phases of flight.

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

NUP

The main objectives of this project are:

- Study the use of VDL (VHF DL) mode 4 for various applications.
- Examine the certification requirements for these applications.
- Develop the airborne and ground ADS-B equipment.
- Examine the frequency allocation problems.

RESET

It identifies, per flight phase, feasible SM reductions contributing to safely reaching the traffic increase.

It also develops methods to safely (fulfilling ICAO/ESARR requirements) and cost-effectively assess the prioritised separation minima reductions. This includes developing a multi-criteria assessment method that will be able to integrate and synthesize results of the Safety, Human Factors, Efficiency and Economy Assessments.

Safe flight 21

The Safe Flight 21 program is developing and evaluating the use of Automatic Dependent Surveillance – Broadcast (ADS-B) capabilities for providing highly accurate aircraft location, identification, and status (e.g., altitude, ground speed, heading) to air traffic controllers on their radar displays and to other pilots via a Cockpit Display of Traffic Information (CDTI).

IV Relevant standards & regulations listing

In order to establish a regulatory background to the A^3 ConOps, official documentation regarding ATM procedures has been identified. It has been decided to focus on ICAO documentation, since it provides the broadest and most internationally accepted position on this matters.

- **ICAO Annex 2 to the Convention on International Civil Aviation – Rules of the Air**
    - Contains the International Standards – Rules of the Air, which govern, together with the Standards and Recommended Practices of Annex 11, the application of the PANS-ATM (Doc 4444), and the *Regional Supplementary Procedures* – Rules of the Air and Air Traffic Services, contained in Doc 7030.
    - The text of the Annex is used without major changes to the text, in the national regulations of the majority of the Contracting States.

- **ICAO Annex 10 to the Convention on International Civil Aviation – Volume III – Communication Systems**
    - Standards and Recommended Practices for Aeronautical Telecommunications were first adopted by the ICAO Council on 1949, and restructured to current configuration as a result of the adoption of Amendment 70 on 1995.

- **ICAO Annex 10 to the Convention on International Civil Aviation – Volume IV – Surveillance Radar and Collision Avoidance Systems**
    - Volume IV of Annex 10 deals mainly with two systems: SSR and ACAS.

- **ICAO Annex 11 to the Convention on International Civil Aviation – Air Traffic Services – Air Traffic Control Service, Flight Information Service, Alerting Service**
    - The Standards and Recommended Practices in this document, together with the Standards in Annex 2, govern the application of the “Procedures for Air Navigation Services — Air Traffic Management” and the “Regional Supplementary Procedures — Rules of the Air and Air Traffic Services”. Annex 11 pertains to the establishment of airspace, units and services necessary to promote a safe, orderly and expeditious flow of air traffic. A clear distinction is made between air traffic control service, flight information service and alerting service.

- **ICAO Doc 4444 ATM/501 Procedures for Air Navigation Services – Air Traffic Management (PANS-ATM)**
    - The Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM) specify, in greater detail than in the Standards and Recommended Practices, the actual procedures to be applied by air traffic services units in providing the various air traffic services to air traffic.

- **ICAO Doc 7030 Regional Supplementary Procedures (SUPPS)**
    - They form the procedural part of the Air Navigation Plan developed by Regional Air Navigation (RAN) Meetings to meet those needs of specific

areas which are not covered in the worldwide positions. They complement the statement of requirements for facilities and services contained in the Air Navigation Plan publications.
  - PANS and SUPPS are approved by the Council, the PANS being recommended to Contracting States for worldwide use, whilst the SUPPS are recommended to Contracting States for application in the groups of flight information regions to which they are relevant.

- **ICAO Doc 8168 Procedures for Air Navigation Services – Aircraft Operations (PANS-OPS) – Volume I: Flight Procedures**
  - Volume I of the PANS-OPS describes operational procedures recommended for the guidance of flight operations personnel and flight crew. It also outlines the various parameters on which the criteria in Volume II are based so as to illustrate the need to adhere strictly to the published procedures in order to achieve and maintain an acceptable level of safety in operations.

- **ICAO Doc 8168 Procedures for Air Navigation Services – Aircraft Operations (PANS-OPS) – Volume II: Construction of Visual and Instrument Flight Procedures**
  - Volume II is intended for the guidance of procedures specialists and describes the essential areas and obstacle clearance requirements for the achievement of safe, regular instrument flight operations. It provides the basic guidelines to States, and those operators and organizations producing instrument flight charts that will result in uniform practices at all aerodromes where instrument flight procedures are carried out. Both volumes present coverage of operational practices that are beyond the scope of Standards and Recommended Practices but with respect to which a measure of international uniformity is desirable.

- **ICAO Doc 9426-AN/924 Air Traffic Services Planning Manual**
  - The manual contains information which can, or should, be taken into account in the formulation of development programmes within States or regions, and also material which can, or should, be applied directly to the planning and operation of the ATS system.
  - To this extent, the manual consists of the guidance material that was previously contained in various attachments to *Annex 11 - Air Traffic Services* and the *Procedures for Air Navigation Services - Rules of the Air and Air Traffic Services* (PANS-RAC, Doc 4444 – previous version of the current PANS-ATM), updated as necessary to reflect latest developments, and also new material concerning important aspects of ATS planning which had not been covered until the publication of this document.

- **ICAO Doc 9574-AN/934 Manual on Implementation of a 300 m (1000 ft) Vertical Separation Minimum Between FL 29' and FL 410 Inclusive**
  - The basic purpose of this manual is to provide regional planning groups (RPGs) with a basis for the development of documents, procedures and programmes to enable the introduction of a 300 m (1 000 ft) VSM above FL 290 within their particular regions in accordance with the criteria and requirements developed by ICAO. More detailed justification and

explanation of the various criteria, requirements and methodology outlined in this manual are provided in the report of the RGCSP/6 Meeting (Doc 9536).

- It also provides:
  - guidance to State aviation authorities on those measures necessary to ensure that the criteria and requirements are met within their area of responsibility; and
  - background information for operators to assist them in the development of operating manuals and flight crew procedures.

- **ICAO Doc 9613-AN/937 Manual on Required Navigation Performance (RNP)**
  - Required Navigation Performance (RNP) is defined as a parameter describing lateral deviations from assigned or selected track as well as along track position fixing accuracy on the basis of an appropriate containment level. RNP types specify the minimum navigation performance accuracy required in an airspace.
  - This manual explains the concept and provisions of RNP, identifies how RNP affects the system providers and system users, and provides regional planning groups with a basis for the development of documents, procedures and programmes to introduce RNP into the airspace.

- **ICAO Doc 9689-AN/953 Manual on Airspace Planning Methodology for the determination of Separation Minima**
  - The primary objective of this manual is to guide airspace planners, ICAO Regional Offices and the regional planning groups and to assist them with implementation of CNS/ATM systems, particularly in relation to airspace planning, implementation of the required navigation performance (RNP) concept and area navigation techniques.
  - The methodology presented in this document provides a framework by which airspace characteristics, aircraft capability and traffic demand can be assessed for the purpose of determining safe separation minima for en-route operations.

- **ICAO Doc 9854-AN/458 Global Air Traffic Management Operational Concept**
  - This document presents an operational concept which is intended to guide the implementation of CNS/ATM technology by providing a description of how the emerging and future ATM system should operate. This, in turn, will assist the aviation community to transition from the air traffic control environment of the twentieth century to develop the integrated and collaborative air traffic management system needed to meet aviation’s needs in the twenty-first century.

- **ICAO Doc 9750-AN/963 Global Air Navigation Plan**
  - This updated and revised version of the Global Air Navigation Plan for CNS/ATM Systems, re-titled as the Global Air Navigation Plan, was developed in consideration of the operational concept and the Strategic Objectives of ICAO.
  - It contains near and medium term guidance on air navigation system improvements necessary to support a uniform transition to the ATM system

envisioned in the operational concept. Long-term initiatives will be added to the Global Plan as the technology matures and the supporting provisions are developed.

- In summary, the Global ATM Operational Concept provides the vision. The Global Air Navigation Plan, with its initiatives and associated interactive planning tools, serves as a strategic document providing the planning methodology that will lead to global harmonization.

V Acronyms List

Acronym	Definition
A^3	Autonomous Aircraft Advanced
ACARS	Aircraft Communication Addressing and Reporting System
ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependant Surveillance - Broadcast
ADS-C	Automatic Dependant Surveillance - Contract
AFR	Autonomous Flight Rules
AIS	Aeronautical Information Service
AMAN	Arrival Manager
AMFF	Autonomous Mediterranean Free Flight
ANS	Air Navigation Services
ANSP	Air Navigation Services Provider
AOM	Airspace Organisation & Management
ASAS	Airborne Separation Assistance System
ASAS-TN2	ASAS Thematic Network 2
ASEP	Airborne Separation
ASP	Aeronautical Surveillance Panel
ATC	Air Traffic Control
ATCo	Air Traffic Controller
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATN/CLNP	Air Traffic Network/Connectionless Network Protocol
ATS	Air Traffic Services
ATSEP	Air Traffic Safety Electronics Personnel
CAZ	Collision Avoidance Zone
CD	Conflict Detection
CD&R	Conflict Detection and Resolution
CDM	Collaborative Decision Making
CDTI	Cockpit Display of Traffic Information
CNS	Communication, Navigation and Surveillance
ConOps	Concept of Operations
COTS	Commercial Off-The-Shelf
CP	Conflict Prevention
CR	Conflict Resolution
CSZ	Comfort Separation Zone
CTA	Controlled Time of Arrival
DCB	Demand and Capacity Balancing
DL	Data Link
DST	Decision Support Tools
EASA	European Aviation Safety Agency
EGPWS	Enhanced Ground Proximity Warning System
FAA	Federal Aviation Administration
FFAS	Free Flight Airspace (outdated)
FMS	Flight Management System
FOC	Flight Operations Centre

Acronym	Definition
GA	General Aviation
GNSS	Global Navigation Surveillance System
HF	Human Factors
HMI	Human Machine Interface
HS	Head of State
ICAO	International Civil Aircraft Association
IFR	Instrumental Flight Rules
IOC	Initial Operational Capability
IP	Implementation Package
IP	Internet Protocol
LoC	Lines of Change
LoS	Loss of Separation
LTACD	Long Term Area Conflict Detection
LTAZ	Long Term Awareness Zone
MA	Managed Airspace
MEL	Minimum Equipment List
MET	Meteorological Service
MOC	Minimum Obstacle Clearance
MSZ	Minimum Separation Zone
MTAZ	Medium Term Awareness Zone
MTCD&R	Medium Term CD&R
NFU	Non-FOC Airspace User
NOP	Network Operations Plan
NVFR	Night Visual Flight Rules
OI	Operational Improvement
OPSP	Operations Panel
PANS	Procedures for Air Navigation Services
PAZ	Protected Airspace Zone
P-RNAV	Precision Area Navigation
R/T	Radio Telecommunications
RAA	Restricted Airspace Area
RBT	Reference Business Trajectory
RNP	Required Navigation Performance
RNPC	RNP Capability
RSP	Required Surveillance Performance
RTA	Required Time of Arrival
RTD	Research, Technology and Development
S&M	Sequencing and Merging
SA	Situational Awareness
SARP	Standards and Recommended Practices
SASP	Separation and Airspace Safety Panel
SBT	Shared Business Trajectory
SES	Single European Sky
SESAR	SES Advanced Research
SFM	Strategic Flow Management
SI	Spacing Interval
SM	Separation Minima
SSAS	Self Separation airspace

Acronym	Definition
SSEP	Airborne Self Separation
SSR	Secondary Surveillance Radar
STAZ	Short Term Awareness Zone
STCD&R	Short Term CD&R
SVFR	Special Visual Flight Rules
SWIM	System Wide Information Management System
TA	Traffic Alert
TBD	To Be Defined
TCAS	Tactical Collision Avoidance System
TCP	Trajectory Change Point
TIS-B	Traffic Information Service - Broadcast
TIS-C	TIS-Contract
TMA	Terminal Manoeuvring Area
TS	Trajectory Synthesizer
TTF	Traffic To Follow
UA	Unmanaged Airspace
UAV	Unmanned Air Vehicle
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
WHA	Weather Hazard Areas
WP	Work Package
WXR	Weather Radar

VI List of references

VI.1 Documents

1. Airborne Separation Assistance System Thematic Network 2 (ASAS-TN2). Work Package 3. *ASAS application maturity assessment*, March 2008

2. FAA/EUROCONTROL Cooperative R&D, Action Plan 1, *Principles of Operation for the use of ASAS*, June 2001.

3. FAA/EUROCONTROL Cooperative R&D, Action Plan 23: Long term ADS-B and ASAS Applications, *The Operational Role of Airborne Surveillance in Separating Traffic*, version 0.1, December 2007.

4. FAA/EUROCONTROL Cooperative R&D, Action Plan 23: Long term ADS-B and ASAS Applications, *D4 – Draft Proposal for a Second Set of GS/AS Applications*, draft version, April 2008.

5. Hoekstra, J.M., *Designing for Safety: the Free Flight Air Traffic Management Concept*. Proefschrift, Technische Universiteit Delft, 2001.

6. ICAO, *Human Factors Digest No.11. Fundamental Human Factors in CNS/ATM Systems*; Int. Civil Aviation Organization, Circular 249-AN/149, 1994.

7. iFly Project, Work Package 1, *Deliverable D1.1 – Autonomous Aircraft Advanced (A^3) High Level ConOps Element Description*, March 2008.

8. iFly Project, Work Package 1, *Deliverable D1.2 – Autonomous Aircraft Advanced (A3) Airline Strategy Concept*, November 2008.

9. iFly Project, Work Package 2, *Deliverable D2.1 – Description of airborne human responsibilities in autonomous aircraft operations*, December 2007.

10. iFly Project, Work Package 2, *Deliverable D2.2 – Situation awareness, information, communication and pilot tasks under autonomous aircraft operations*, January 2008.

11. INTENT Project, *Deliverable D4-1, Project Executive Summary,* June 2003.

12. Loscos, J.-M. *ASAS activities at the ICAO level: steps towards global standardization*, ASAS-TN2 Final Seminar, Paris, April 2008.

13. Mediterranean Free Flight Programme, Working Area 2, *D220-MFF Operational Concept, Requirements & Procedures,* October 2005.

14. NASA Ames Research Centre, AATT Project Office, *Distributed Air-Ground Trajectory Management Concept Element 5: En-route Free Maneuvering for User-Preferred Separation Assurance and Local TFM Conformance*, September 2004.

15. Next Generation Air Transportation System (NextGen) Joint Planning and Development Office, *Concept of Operations for the Next Generation Air Transportation System*, version 2.0, June 2007.

16. Next Generation Air Transportation System (NextGen) Joint Planning and Development Office, *Integrated Work Plan for the Next Generation Air Transportation System*, version 0.2, February 2008.

17. RTCA, Inc., Special Committee 186 (SC-186), *Minimum Aviation Performance Standards For Automatic Dependent Broadcast (ADS-B)*, June, 2002.

18. SESAR Consortium, SESAR Definition Phase Project, *Deliverable 1 – Air Transport Framework – The Current Situation*, 2006.

19. SESAR Consortium, SESAR Definition Phase Project, *Deliverable 3 – The ATM Target Concept*, 2007.

20. SESAR Consortium, SESAR Definition Phase Project, *Deliverable 4 – The ATM Deployment Sequence*, 2008.

21. SESAR Consortium, SESAR Definition Phase Project, *Deliverable 5 – SESAR Master Plan*, 2008.

22. RESET RST-WPX-AEN-033 - List of reduced separation standards for prioritization - Technical Report-V1.1

23. Doble, Barhydt, Hitt "Distributed Conflict Management in En Route Airspace: Human-in-the-loop Results". DASC2005

24. HYBRIDGE report D9.4 Sequential Monte Carlo simulation of collision risk in free flight air traffic. H.A.P. Blom, G.J. Bakker, J. Krystul, M.H.C. Everdij, B. Klein Obbink and M.B. Klompstra, 2005. Version: 1.0

25. *Henk A.P. Blom, Bart Klein Obbink, G.J. (Bert) Bakker.* Safety risk simulation of an airborne self separation concept of operation. *Preprint Proceedings 7th AIAA-ATIO Conference, September 18-20, 2007, Belfast, Northern Ireland.*

VI.2 Web Pages

1. Advanced Air Transportation Technologies.
   http://www.asc.nasa.gov/aatt/dag.html

2. ASAS – TN2 Home Page.
   http://www.asas-tn.org/

3. HYBRIDGE Distributed Control and Stochastic Analysis of Hybrid Systems Supporting Safety Critical Real-Time Systems Design.
   http://hosted.nlr.nl/public/hosted-sites/hybridge/

4. ERASMUS. En-route Air Traffic Soft Management Ultimate System.
http://www.atm-erasmus.com/pageoverview.html

5. FAA – System Wide Information Management (SWIM).
http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/swim/

6. FREE FLIGHT. Free Flight with Airborne Separation Assurance.
http://hosted.nlr.nl/public/hosted-sites/freeflight/

7. MFF. Mediterranean Free Flight Programme.
http://www.medff.it/

8. NASA Ames Flight Deck Display Research Laboratory-Distributed Air Ground – Traffic Management.
http://human-factors.arc.nasa.gov/ihh/cdti/dagTm.html

9. NEXTGEN Joint Planning and Development Office.
http://www.jpdo.gov/library.asp

10. RESET. Reduced Separation Minima.
http://reset.aena.es/

11. RTCA Home Page.
http://www.rtca.org/

12. Rule Optimization for Airborne Aircraft Separation.
http://www.eos.tuwien.ac.at/Oeko/Teaching/Theses/dissschild/id120.htm

13. SESAR Consortium Web Page.
http://www.sesar-consortium.aero/

14. SWIM-SUIT (System Wide Information Management Supported by Innovative Technologies).
http://www.swim-suit.aero/swimsuit/