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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

iFly Deliverable D8.3
A^3 equipped aircraft within SESAR´s Concept of Operations

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Abstract

Future capacity problems due to the air traffic increase make necessary a paradigm shift in the Air Traffic Management System. NEXTGEN (Next Generation Air Transportation System) in the USA and SESAR (Single European Sky ATM Research) in Europe are two key programs that set up the basis for the future system in both continents taking into consideration the expected needs from all stakeholders.

iFly studies an advanced airborne self separation concept of operations, which is referred to as named *Autonomous Aircraft Advanced (A^3)* ConOps. The present document aims at the identification of similarities and differences between SESAR2020 and this A^3 ConOps. Subsequently possible paths for transition from SESAR2020 to the this A^3 ConOps are considered;

- *Exclusionary Airspace*, where only A^3 equipped aircraft will be allowed to operate. This Exclusionary Airspace is defined within the en-route airspace and above a certain Flight Level;
- *Airspace Corridors*, where non-A^3 equipped aircraft will operate;
- *Full Use of A^3 Equipment in Non-exclusionary Airspace*, where A^3 equipped and non-A^3 equipped aircraft are permitted with certain restrictions;
- *Partly use of A^3 equipment in Non-exclusionary Airspace*, where A^3 equipped and non-A^3 equipped aircraft are permitted with A^3 aircraft using only part of their capabilities.

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1 Introduction

1.1 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 in current en-route traffic levels***.

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.

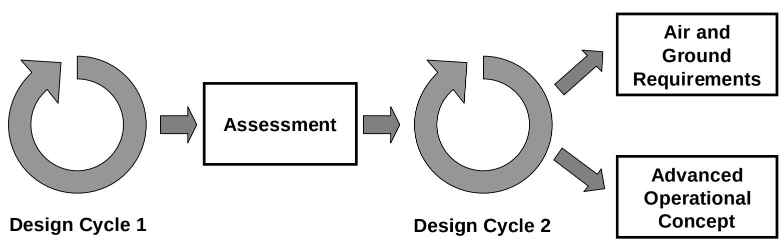

Figure 1 iFly Work Structure

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 centralized and 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.

1.2 iFly Work Package 8 (WP8)

The WP8 refines the A^3 ConOps and develops a vision about how A^3 equipped aircraft can converge and be integrated with the SESAR concept.

SESAR propose to operate in mixed mode environment with self-separating flights and flights being separated by ATCo which means that there will be an ATCo monitoring the self separating aircraft. In order to avoid vagueness and uncertainties, iFly consider absolutely none ATCo at all participating in the A^3 concept and one of its objectives is to find out which traffic demand airborne self separation can be handled safely without any ATCo support at ground.

The first stage of WP8 to achieve this objective is the integration of the mathematical results obtained from previous work packages (WP3, WP4 and WP5) as well as the integration of feed-back from WP2 and WP9.

Following stages are focussed in the A^3 equipped aircraft, how it is aligned with SESAR, non-airborne requirements and operations.

1.3 iFly Work Package 8.3

The objective of the work package 8.3 is to develop the vision of A^3 equipped aircraft operating within SESAR. Therefore the aim of WP 8.3 is to develop a vision how the gradual increase of equipped A^3 aircraft within the SESAR settings should fit best. This will answer the question how well the A^3 thinking combines with the gradual implementation of autonomous aircraft operations, where non A^3 equipped and A^3 equipped aircraft will coexist for a period of time.

Therefore, this is a crucial task for the refinements of the ConOps because of different areas of analysis identified by SESAR are considered.

1.4 Work Document D8.3 Scope

The work document D8.3 is the outcome of the WP8.3. This document takes part of the A^3 ConOps refinement that develops a vision how A^3 equipped aircraft can be integrated with

SESAR concept, besides, it continues the work developed in the WP1, D1.1 aimed to the high level ConOps definition and D1.3 that provides in detail a functional and versatile autonomous aircraft by providing information about several basic topics required for the development or airborne self separation applications.

Specifically WP8.3 is aimed to develop the vision in terms of A^3 equipped aircraft can operate within SESAR, and this deliverable analyses the impact of A^3 ConOps on strategic ATM.

1.5 Organisation of this report

This report is organised as follows. Section 2 gives a summary of the A^3 Conops. Section 3 gives a summary of the SESAR2020 ConOps, and a comparison with the A^3 Conops. Section 4 is dedicated completely to study how a gradual A^3 equipped aircraft will operate in a SESAR environment. To facilitate this approach, some important issues are going to be examined. Section 5 gives concluding remarks.

2 A^3 ConOps Summary

The A^3 ConOps ([1], [2]) is based on key operational improvements from the ASAS-TN2 concept of operations. Its main characteristics ([1], [2]) are summarized in the following sections.

2.1 Airspace and Zones

The A^3 airspace is divided in 3 categories. Their main characterictis are:

Managed Airspace (MA):
- High density areas – TMA Areas and other dynamically designed zones (e.g. Restricted Use of Airspace, Military Airspace);
- The pre-defined separator is the ATC by using ATC clearances;
- IFR, VFR, NVFR, SVFR flights are allowed;

Unmanaged Airspace (UA):
- The pre-determined separator is the Airspace User;
- ATC services are not provided;
- Only VFR and AFR (if aircraft properly equipped) are allowed.

Self Separating Airspace (SSA):
- The boundaries are defined in time and space by means of a dynamic allocation of Managed and Unmanaged airspace;
- ATC is not responsible of the separation within the SSA. This responsibility is on the Flight Crew;
- Ground Up-Link and direct Air - Air Data Link;
- AFR flights and VFR are allowed only below a given altitude (e.g. 19.500 ft. MSL);
- SSR only defined in En-route;
- Flight level structure can be defined, but this is not compulsory;
- User-preferred routing.

iFLY separation is implemented by defining a ***Protected Airspace Zone (PAZ)*** with the following elements:

Minimum Separation Zone (MSZ) is a vertical cylinder centred in each aircraft that other aircraft cannot penetrate in order to maintain the safety levels considered in A^3 Operations;

Comfort Separation Zone (CSZ) is a vertical cylinder centred in each aircraft that provides additional margins for maintaining separation even in the presence of uncertainties.

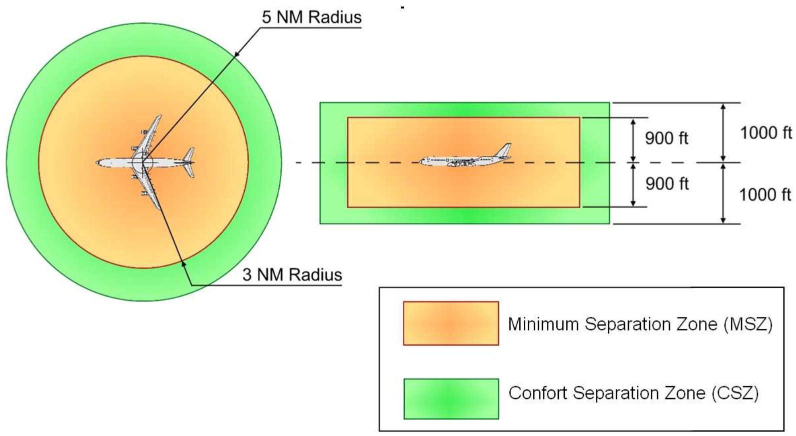

Figure 1 Protected Airspace Zone (PAZ)

iFLY surveillance is managed through the ***Surveillance/Awareness Zones.*** These zones are dynamically defined as a function of the aircraft trajectory in order to enable processing the relevant information from SWIM. Two different zones have been identified and are described below:

Medium term Awareness Zone (MTAZ) covers a dynamic aircraft area for the mid-term timeframe of the aircraft trajectory. Airborne separation tasks are performed within this zone;

Long Term Awareness Zone (LTAZ) covers a dynamic aircraft area for the long-term timeframe of the aircraft trajectory. This information is used to support the flow management processes.

Traffic information related to the short-term timeframe will be obtained through direct air-air communications. For mid and long-term time horizons an important amount of information will be provided through SWIM although air-air communication remains the primary source of information. The available information depending on the previously defined zone can be classified as follows:

- ***State data*** **–** Current position and speed vector, Flight Level priorities and separation class. These data are broadcasted through data link (e.g. ADS-B);
- ***Intent data*****–** Trajectory changes and conformance monitoring data. This data are broadcasted through data link[1] and also provided to SWIM[2];
- **Reference Business Trajectory (RBT) –** Planned 4D trajectory provided to SWIM and FOC (if available). This trajectory is based on State and Intent data and augmented with planned route. This information can be used for dynamic on-board trajectory optimization although not used by other airborne systems.

[1] Air-Air data link (ADS-B) is the primary means of obtaining Intent data
[2] Intent data of aircraft that are not within ADS-B range and are of interest to the aircraft will be obtained through SWIM

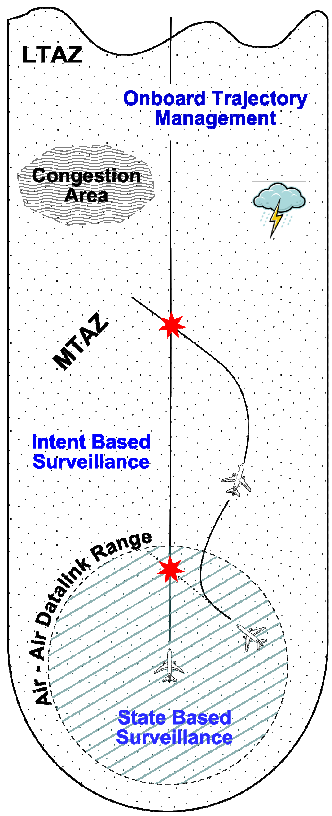

Figure 2 Surveillance/Awareness Zones

Restricted Airspace Areas (RAA), Weather Hazards Areas (WHA) and Protected Airspace Zones (PAZ) can be defined into the SSA.
Restricted Airspace Areas (RAA) are non-moving conflict zones. AFR aircraft are responsible for maintaining the required separation with this restricted airspace;
Weather hazards areas (WHA) are slow-moving & changing conflict zones. AFR aircraft are responsible for maintaining the required separation with these areas. The design of these areas is variable depending upon real meteorological data communicated by the A^3 aircraft and other sources of information (meteorological stations…)

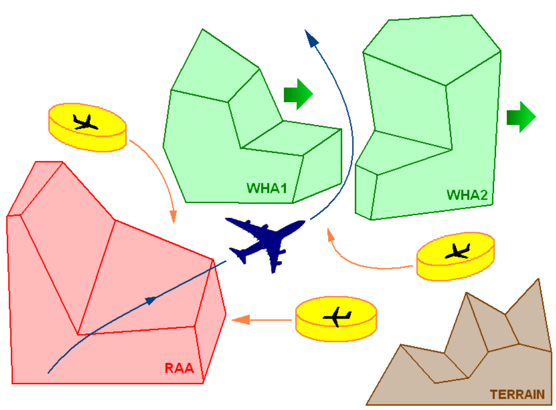

Figure 3 Zones within SSA

2.2 Key Enablers

A^3 key enablers for a suitable operation are the following:

- System Wide Information Management (SWIM);
- Air-Ground and Air-Air Data Link communications and Surveillance Broadcast.Air-Air Data link is used to obtain information on surrounding aircraft. Air-Ground Data link is used to obtain information through SWIM;
- On-Board Decision Support Tools (DCT), including ASAS (Airborne Separation Assistance System);
- Advanced Airborne Automated Applications in order to improve the situational awareness by managing weather data applications, warning functions and guidance algorithms;
- Advanced Ground Surveillance Support in order to inform aircraft of other surrounding traffic and complex/congested areas;
- Advanced Human Machine Interfaces;
- New Procedures;
- New Flight Management System (FMS);
- Airborne Collision Avoidance System (ACAS).

2.3 Flight Planning (Planning Phase)

One of the main processes of the planning phase is the **Pre-flight Strategic Flow Management (SFM).** This process provides a network operations plan strategically de-conflicted and conflict-free by refining the Shared Business Trajectories (SBT) provided by the airspace users. The main characteristics of the SBT are:

- SBT contains all trajectory data expressing the user's preferences;
- SBT is published in SWIM in order to make the information available to all airspace users and ANSPs;
- SBT ensures a conflict-free trajectory from TMA exit to TMA entry;
- SBT avoids creation of excessive complexity;
- SBT balances the interests of FOC and NFU;
- SBT ensures smooth operations for the airports.

The main actors involved in the SFM process are:

- FOC (Flight Operations Centres). Responsible for the safe planning and conducting their own airliners flights (and external fleets which pay for their services). They are involve in Strategic Flow Management and In-flight Monitoring.
- NFU (Non FOC Airspace Users) include Charter, low-cost airlines, Business jets, General aviation and Military and Official aircraft.
- ANSPs (Air Navigation Service Providers). Responsible for the assignments of entry constraints at arrival TMA and participate on the transitions at TMA. Given that separation responsibility is delegated to the aircraft, the ANSPs' major role is to manage SWIM and the ground support tools that enables SWIM to exchange information.

Next figure shows the relations between main actors involved in the planning operation processes.

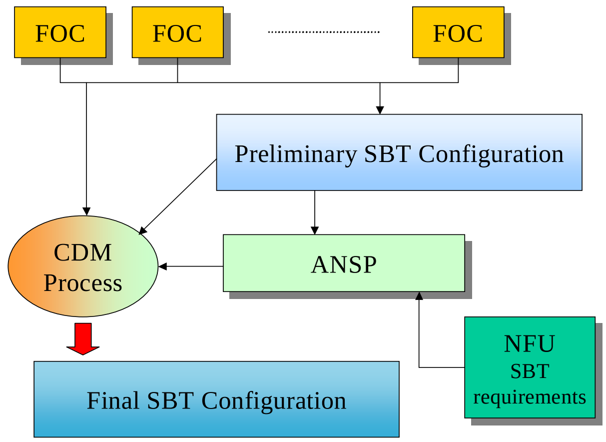

Figure 4 Pre-flight CDM Process

2.4 Flight execution (Tactical Phase)

The main processes of the A^3 ConOps in the tactical phase are shown in figure 6 and described below. The starting point of these processes is the consolidation of the Reference Business Trajectory (RBT) which is generated from the up-to-date SBT as soon as take-off time is known for a given aircraft;

1. TMA ATCo ensures aircraft is conflict free when entering SSA. RBT is active and available to all partners through SWIM. Controlled Time of Arrival (CTA) is assigned at arriving TMA by the ANSP. AFR flights becomes autonomous;
2. Aircraft flies RBT provided by the FMS. Its state and intent, separation class and priority level is broadcasted through Air-Air Data Link. These data are also provided to SWIM. Information from other aircraft and through SWIM is received and integrated with weather forecast, area updates and on-board sensors information. FOC monitors the flight thanks to the information in SWIM;
3. CTA may be re-negotiated by the flight crew (reflect course of flight) or TMA ATCo (purpose of flow management).
4. The CTA is fixed and the flight is included in the AMAN sequence (CFMU will manage the sequence through SWIM in airports without AMAN);
5. Aircraft reaches arriving TMA, ceases to perform self-separation and is controlled again by ATCos.

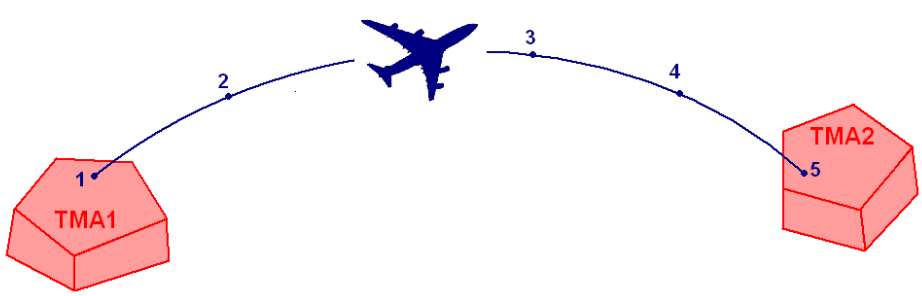

Figure 5 A^3 basic flight description

All aircraft flying inside SSA have to fly according to AFO (Autonomous Flight Operations), what means that:

- Each flight crew has the responsibility for self-separation.
- Each aircraft has to fly according to specific Autonomous Flight Rules (AFR);
- When all equipment is working normally, aircraft conduct Normal Operations;
- When there is a degraded situation, but the remaining performance of the overall system is such that self-separation can be maintained, then aircraft conduct Non-normal Operations. Such degraded situation can be due to:
    - On board equipment performance;
    - Flight crew performance;
    - SWIM network performance,
    - Aircraft performance.

The Autonomous Flight Rules (AFR) that each aircraft (flight crew) has to follow are the following:

- Aircraft is responsible for maintaining separation with all other aircraft;
- Aircraft is required maintaining separation from designated areas and no-fly zones;
- Aircraft is required adhering to flow management constraints;
- Manoeuvres to solve mid-term conflicts are defined and performed sufficiently in advance;
- Manoeuvres that potentially create a short-term (3-5 min) conflict are not allowed;
- Trajectory shall at no time place the aircraft in a 2 min state vector conflict;
- Flights are not allowed entering managed airspace without approval.

Each flight crew could modify their own trajectory without negotiation with ATC due to conflicts with other aircraft, hazards (areas-to-avoid[3] or areas-recommended-to-avoid[4]) or changes in the users' preferences.

Conflicts in the A^3 environment are identified when the Protected Airspace Zone (PAZ) is predicted to be penetrated by a Restricted Airspace Area (RAA), a Weather Hazard Area (WHA), a Terrain/Obstacle restriction or by other aircraft. Then, Loss of Separation (LoS) may occur if no action is taken. LoS occurs if the lateral and vertical distance between 2 aircraft is less than the PAZ dimensions. LoS with the Minimum Separation Zone (MSZ) should be prevented at all times. The look-ahead time for Conflict Detection (CD) between 3 to 5 min for State based CD and 15-20 min for Intent based CD.

Conflict Detection and Resolution modules based on the look-ahead time for detection are explained below (See figure 7):

Long-Term Area Conflict Detection **(LTACD)** applies to LTAZ and detects any conflicts with "areas to avoid".
Resolution is provided by the Trajectory Management Module;
Medium-Term Conflict Detection and Resolution **(MTCD&R)** takes into account own flight trajectory intent information and information of surrounding traffic (up to 15 – 20 minutes);
Resolution modules use priorities between aircrafts to solve conflicts. Priorities will take into account CTA requirements (fixed CTA implies the highest priority),

[3] Sever hazards (weather, restricted areas, etc)
[4] Less severe hazards

Manoeuvrability (Speed envelope, Turning radius and Climb rate), and Mission Statement (non –normal and emergency have higher priority levels). Aircraft with lower priority always have to manoeuvre. Identical Priority levels will be resolved by the use of an arbitration procedure. The priority status will be broadcasted.
Resolutions are displayed in the form of a modified route. These resolution routes can be implemented automatically or manually through the FMS. Flight crew should be able to evaluate several conflict free resolutions options and execute any given manoeuvre without creating other conflicts. Resolution algorithms ensure that at no time during the flight, the aircraft trajectory will place the aircraft in a 2 minute state vector conflict.

Short Term Conflict Detection and Resolution (STCD&R) module considers the best traffic information available up to the 3 to 5 minutes range.
Short Term Conflict Resolution module enables a quick execution involving fast automated assessment and calculations. This module presents simple manoeuvre options to the flight crew. Resolution module primary focus is on conflict resolution execution instead of trajectory management. There will be no direct communication between aircraft for manoeuvre coordination. They will be implicitly coordinated.
Implicitly coordinated requires that all aircraft use compatible resolution algorithms with a cooperative set of resolution manoeuvres. Short Term traffic Conflict Resolution algorithms are able to resolve conflicts which involve several other aircraft (‘1 on N’ capability), and not create new conflicts. The resolution algorithms ensure that at no time during the flight, the aircraft trajectory will place the aircraft in a 2 minute state vector conflict.
Airborne Collision Avoidance System (ACAS), in the form of TCAS-II.
An ACAS system will act as a back-up system and independently of in-flight ATM functions.

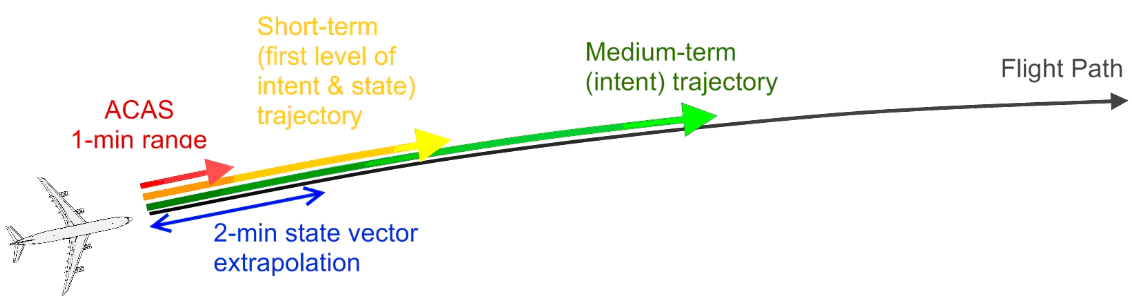

Figure 6 CD&R look ahead time

The following table summarizes the main characteristics explained above of each module:

	Look ahead time for CD	Coordination	Principle of use	Priority Rules	Do not create secondary Conflict	Type of resolution algorithm
LTACD[5]	>30 min	Not applicable	RBT	Not app.	Not app.	No resolution
MTCD&R[6]	Up to 15 to 20 min	Not required	Intent	YES	Do not	Intent Based
STCD&R[7]	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

All CD and CR modules work in parallel. Conflict Processing module on the aircraft may assign conflicts coming from any CD module to the appropriate CR module.

Conflict Resolution coordination requires an unambiguous definition of Mid-Term and Short Term Conflicts:

- Short Term Conflict: The conflict Resolution manoeuvre which starts at TTL8< STT9 , and fulfils the implicit coordination requirements
- Mid Term Conflict: The conflict resolution manoeuvre which starts at TTL > STT, not needs to be coordinated but priority rules must be respected

The whole process of conflict resolution leads to one of the type of conflict solutions explained above. Conflict resolution process comprises three main steps:

- TTL when a conflict was detected determines whether the manoeuvring is required. The aircraft shall do it if TTL < STT or it has lower priority number than the other conflict aircraft involved.
- Conflict processing logic determines the appropriate form of conflict solution
- RTTL10 (for the selected conflict solution) determines if the implicit coordination shall be used

The coordination is expected to be:

- Explicit 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.

[5] LTACD: Long Term Area Conflict Detection
[6] MTCD&R: Medium Term Conflict Detection and Resolution
[7] STCD&R: Short Term Conflict Detection and Resolution
[8] Time To predict Loss of separation: Time span between the actual time and PLOS (Predicted Loss of Separation)
[9] Short Term time Threshold: TTL threshold
[10] Remaining Time To Loss of separation: Time period between PLOS and the estimated moment when the execution of a conflict solution starts.

Resolution algorithms on CR modules considered:

- "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.
- "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 resolves the most critical conflict first.

Algorithms have to check the extended state vector at Trajectory Change Points (TCP) for possible state conflicts.CR algorithm implementations also provide useful alternatives in case pilots reject the provided solution.

There are two forms of conflict solution:

- Open manoeuvre, solves a conflict situation but a consistent continuation of the flight after the manoeuvre is not considered (does not have a consistent RBT when it starts to execute it). Requires shorter conflict processing
- Close manoeuvre, provides a consistent RBT update. It requires longer onboard conflict processing

Onboard conflict processing, in a high and general level, starts after detection of the conflict, then, the event/situation is assessed and a suitable conflict resolution method is chosen. The method solves the situation based on the updated information available and presents a proposed solution(s) to the flight crew, the solution is initiated and at the same time the new intent is broadcasted.

2.5 Flight Crew: Roles and Responsibilities

Flight Crew plays a major role in A^3 concept because is the sole separator of traffic and all other hazards.

Flight crew is responsible for the safe, efficient and on-time operation of the flight. Also fligh crew is responsible for separation with all other aircraft and adhering to flow management constraints.

Task performed by flight crew are listed below:

- 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
- 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 data communications.

Additional tasks and increasing traffic are not expected to represent an unmanageable increase in current flight crew workload during the en-route phase of flight. These have to be achieved with adequate automation assistance and efficient congruence of functions carried out by automation and crews. Also a reduction in several tasks that currently pose a rather heavy burden in flight crew workload, such as voice communication or radio frequency changing or sector monitoring are planned to be made.

Utilization of new Decision Support Tools will help to reduce mental workload. All actions suggested by the onboard Decision Support Tools that influence the flown trajectory shall be approved by the flight crew.

The primary guidance mode of operation will be through FMS and fully automated. Crews may (at their own choice) 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).

Flight crew will manage the flight at different levels:

- 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.
- 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.
- Tactical/Medium term conflict detection and avoidance: using traffic intent and state information from Air – Air DL and supplemented by SWIM.
- Short term conflict detection and avoidance.

Flight Crew is in the loop during all phases, to be aware of the system status and to be able to take-over when system fails

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

Pilot’s workload shall be kept within acceptable limits, to achieve this goal 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;
- Design adequate tools enabling an adequate task allocation between human and automation and 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, and should not lead to long head down time.
- False alarms have to be considered.

Also a necessity of training will appear:

- Pilots as well as Air Traffic Controllers must be familiarized with all changes. 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.

2.6 Communications and supporting systems

A suitable architecture on ground and onboard for supporting the use of business trajectory and assuring self separation has to be developed to ensure a suitable operation based on a stronger communications, data transmission and information sharing network.

There are two main types of information to be exchanged, information broadcasted by the aircraft and information provided to/by a ground supporting system (SWIM).

Next procesess used communications as a main source:

- Information about/Requests for flight/trajectory changes.
- Data exchange for distributed decision making.
- Digital audio/video transmissions.
- Shared data exchange with SWIM.
- Voice communication will remain the backup means of communication in non-standard or emergency situations.

The communication network will enable data transmission, particularly, point to point data transfer (air to ground, ground to air, air to air) and broadcast data transfer (air to air and air to ground).

The aircraft shall broadcasted the information about own flight and shall announce any changes of its RBT to SWIM immediately.

2.6.1 Ground Systems

The information sharing network is based on the System Wide Information Management network (SWIM), which become the main actor for systems on ground.

SWIM will provide different means to obtain data:

- Pull-model: Some data will be available “upon request” (query), e.g., latest state and intent data of aircraft in its proximity.

- Push-model: Some data will be periodically sent to the aircraft, e.g., Areas to avoid, weather information, list of relevant aircraft IDs.

The information available in SWIM (see Figure 8) is:
Concerning trajectory data:

- SBT, pre-flight trajectory information
- RBT, flight trajectory information while the aircraft is flying, manoeuvres made by the aircraft, CTA actualizations and trajectory changes in-flight are reflected
- RTA, fixed CTA when the aircraft is getting closer to the destination airport (higher priority level in the arriving phase)
- CTA, the initial CTA and the refined ones along the flight
- RBT Conformance, status message at certain intervals

Concerning aircraft data:

- Aircraft State, comprises position, velocity, course & altitude information, aircraft ID, separation class and priority level tag , for MTCR
- Aircraft Intent, consist on trajectory change points (TPCs) and conformance monitoring data
- Aircraft SM Class, tag concerning operating in normal or not- normal conditions

Concerning aircraft equipment data:

- Aircraft Navigation Equipment Status, status message informing about the whether or not the navigation equipment on board is properly working
- Aircraft ASAS Equipment Status, status message informing about ASAS performance level on board
- Aircraft System Status, status message informing about other systems performance on board related with self-separation.

Concerning environment data:

- Weather, all type of meteorological data and measured air data, about forecasted wind and temperature conditions
- Airspace, operational restrictions in the form of areas to avoid
- Congested/Complex Areas Information, information about this areas (used in LTAZ)
- MTAZ Proximity Traffic, notifications of all surrounding traffic in their MTAZ

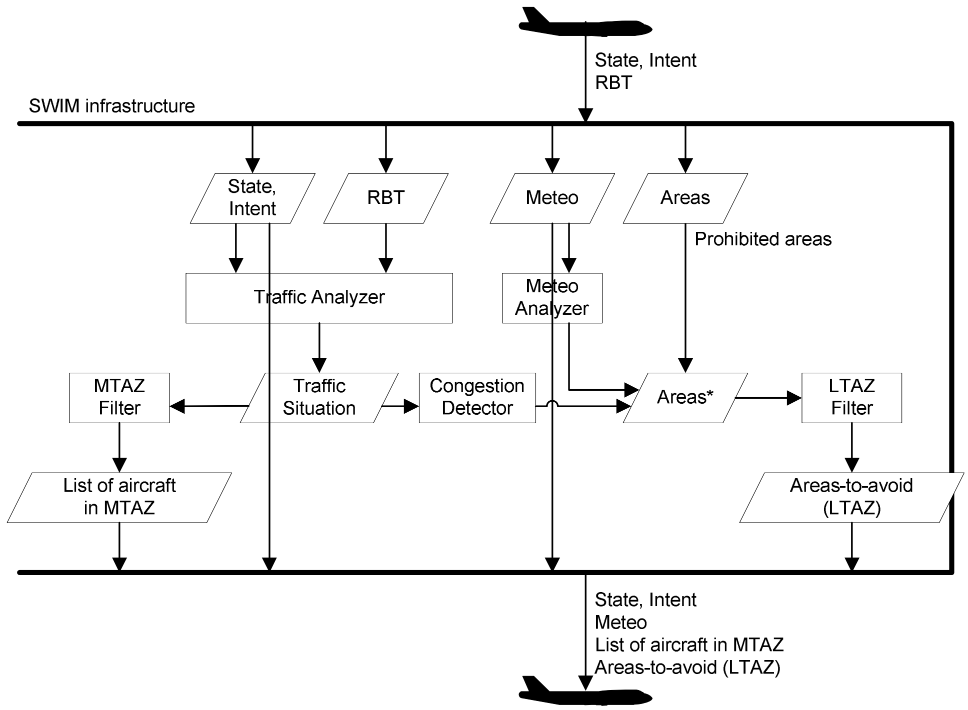

Figure 7 SWIM architecture

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, are foreseen:

For MTAZ a fully automated information sharing mechanism with the ground surveillance tools is considered:

- A Traffic Proximity Detection11 function will 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[12].

SWIM surveillance and information communication exchange is clarified in Figure 9.

[11] 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.

[12] Automated tool that uses the RBTs to evaluate a suitable traffic complexity metric across the airspace. Based on the predefined threshold(s) complex areas are detected and together with other areas-to-avoid provided to aircraft.

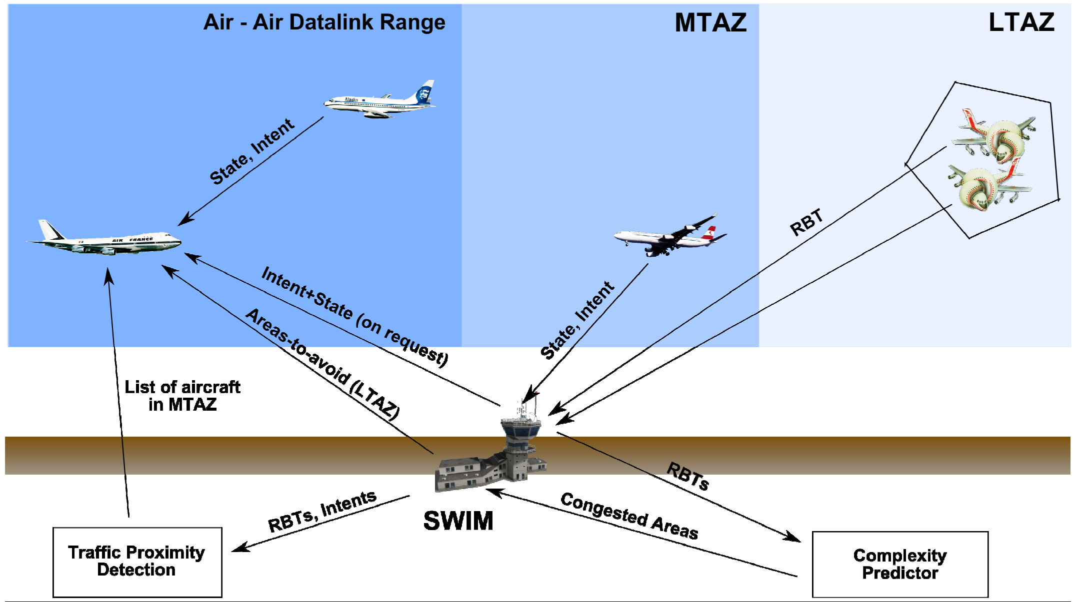

Figure 8 SWIM Information Exchange

2.6.2 Cockpit Systems

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

Three new airborne applications & functionalities will be needed:

- Information Processing Unit – that gathers information from external sources and categorises these into appropriate data sets, is responsible for the communication with SWIM.
- 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 next figure

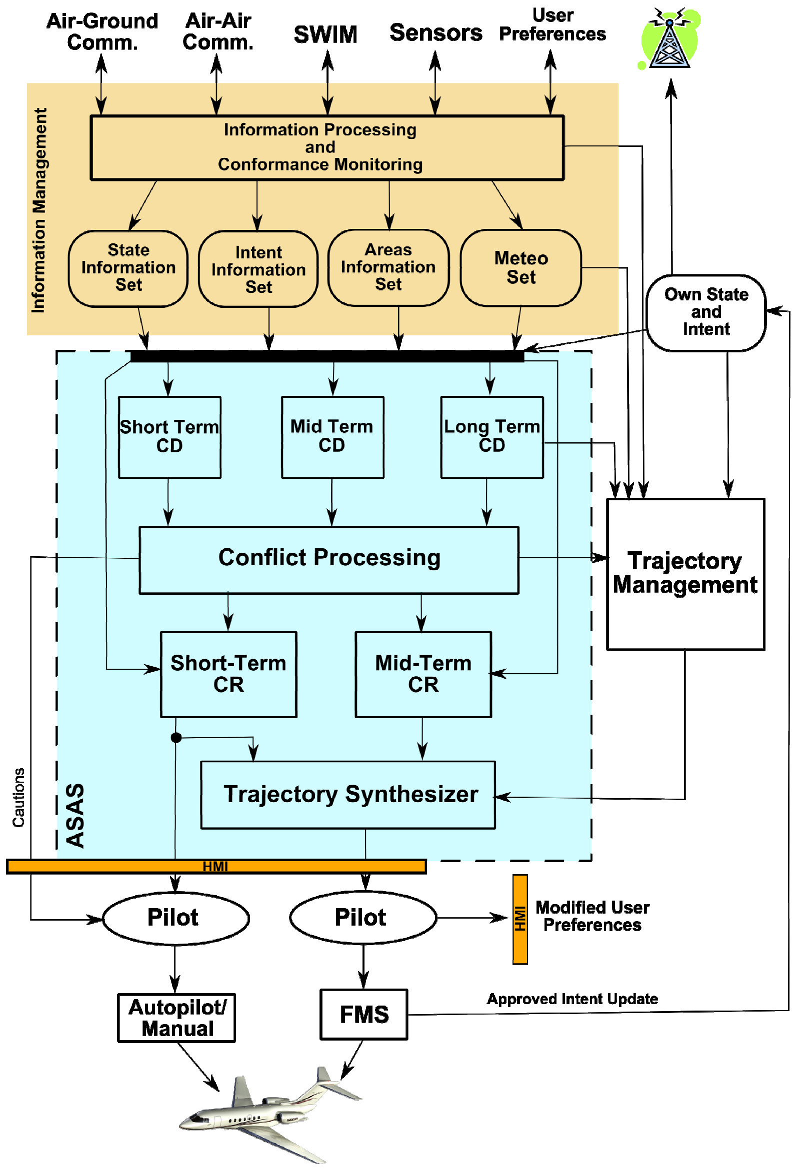

Figure 9 Airborne System architecture

Information Processing Unit

This system will receive surveillance data from airborne and ground based surveillance functions:

- 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 Enhanced Ground Proximity Warning System (EGPWS).

The system will provide the highest possible precision, detecting 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 system will therefore indicate a confidence level for the supplied information.

The main goal of the information processing unit is to keep updated the four on-board information sets:

- State traffic information set – contains all updated state information (position & velocity vectors, priority level and separation class) coming mainly from direct air-air communication
- Intent traffic information set – contains updated 4D trajectories (state and intent trajectories) of all aircraft crossing the MTAZ. The trajectories are based on the data obtained via direct Air-Air Data Link channels or automatically queried from SWIM.
- 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).
- 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.

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.

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 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 or modify the proposed new trajectory by altering its parameters before acceptance.

3 SESAR ConOps Summary

The key elements of the SESAR ConOps are described in the present section. The following information is based on the deliverables The ATM Target Concept D3[13], European ATM Master Plan[14] and D3 SESAR Concept of Operation[15]. These three documents were produced during the SESAR Definition Phase.

A^3 timeframe is beyond the SESAR timeframe (2020). Consequently, the main assumption of the present analysis is that SESAR ConOps will be deployed and fully operational before the A^3 ConOps is implemented. Thus, the A^3 Conops can be viewed as an extension over the SESAR 2020 ConOps.

3.1 Airspace and Zones

SESAR Airspace is organised in 2 categories in a service-oriented approach. Their main characteristics are:

Managed Airspace.

- All traffic information is shared;
- ANSP is the pre-determined separator, but this role may be delegated to the flight crew;
- User-preferred routing will apply in the cruising level of managed airspace, 16
- User-preferred routes should take into account restricted/segregated volumes.
    - Fixed Volumes, such as danger areas (e.g. artillery areas), environmental and secured sensitive areas;
    - Dynamic and Variable Airspace Reservations Temporary Volumes due to military activities mainly17;

Unmanaged Airspace.

- The Airspace User is the pre-determined separator.

[13] D3- The ATM Target Concept DLM-0612-001-02-00a v2.0

14 The European ATM Master Plan DLM-0710-001-02-00 v1.0

[15] D3 Concept of Operations DLT-0612-222-02-00 v2.0

[16] However, route structures will be available for operations requiring such support (aircraft with lower capabilities), or when the traffic density/complexity requires their deployment. Near major hubs, the entire area below a certain level will be operated as an extended TMA with route structures eventually extending also into the en-route airspace.

[17] . In this case, the segregated airspace will be minimised both in space and time.

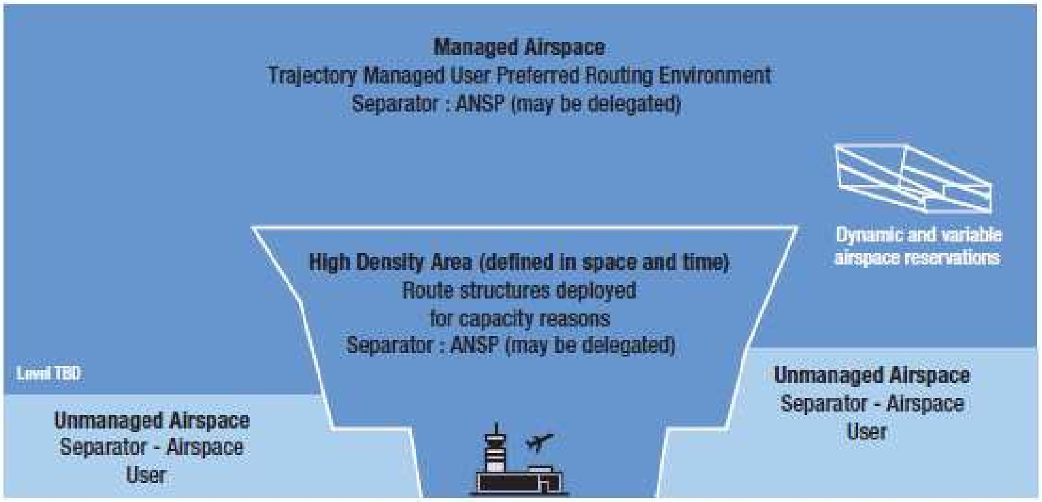

Figure 10 SESAR Airspace organisation

Finally, Managed Airspace can be classified in low, medium or high density/complexity airspace. The necessary services to support operations are related to this classification. The same airspace volume may dynamically change its classification along the day of opertions (e.g. high density area during the day and medium at night).

3.2 *Key Enablers*

Key enablers supporting this concept are:

- System Wide Information Management (SWIM). Net-centric system where the ATM network is built upon multiple nodes providing or consuming information (including the aircraft);
- Collaborative Decision Making (CDM). Decisions are made on the basis of common situational awareness which improves the capability for taking decisions;
- Network Management. Collaborative layered planning processes mediated by Sub-regional and Regional Network Managers ensure the achievement of a stable demand and capacity balance. The Sub-regional and Regional Network Managers mediate through a set of collaborative applications providing access to traffic demand, airspace and airport capacity constraints and pre-defined scenarios to assist in managing diverse events;
- Airports are integrated as a node of the network. Airports will be included in the trajectory management processes, and several measures will be in place to help achieving the airport target capacity;
- Airspace Capacity. Design of airspace to match trajectory-based management approach is crucial in permitting the ATM system to provide the right services. This includes the route/non-route structures, new separation modes (including delegation of separation tasks to the pilot), and air/ground data link communications;
- New airborne separation modes, such as ASAS Self Separation in mixed-mode operations, will allow self-separating flights and ANSP-separated flights operating in the same airspace18

[18] Nevertheless, it must be proven that this mixed mode of operations meets the target level of safety in addition to providing economic and capacity benefits, and before mixed mode operation is achievable, designated parts of

SESAR has identified the next operational improvements and enablers related to self-separation:

- Self-separation is extended to all airspace to allow mixed-mode operations. This self-separation mode needs the authorization of the controller. This will avoid segregation of flights due to aircraft capabilities and facilitate access to all users. Ground systems will have to provide the required service to less capable users without penalising others. System and procedural enablers needed are:
    - High performance of Air-Ground Datalink;
    - Air-Air Datalink;
    - Advanced ADS-B link;
    - Flight management and guidance to support ASAS self-separation;
    - On-board conflict detection and resolution to support ASAS self-separation;
    - Air broadcast and reception of aircraft trajectory, weather, and wake-vortex data (ADS-B IN/OUT);
    - Enhanced Controller Tools to support the delegation of separation in a mix-mode environment;
    - ATC procedures for assessing and issuing approval for ASAS self-separation applications;
    - ATC procedures for regaining responsibility and establishing separation during non-nominal events;
    - ATC procedures for ensuring separation/spacing between self-separating and other aircraft in mixed-mode operations;
    - Cockpit procedures to perform self-separations.
- Self-Adjustments of spacing depending on the Wake Vortex. The aircraft will measure its wake vortex characteristics. This information will be broadcasted to neighbouring aircraft. System enablers needed are:
    - Broadcast of aircraft position/vector (ADS-B OUT);
    - Airborne traffic situational awareness to support in flight operations;
    - Reception of air broadcast of aircraft position/vector (ADS-B IN);
    - FMS performance standards;
    - Flight Management and guidance to support ASAS spacing (ASPA);
    - Up-link and automatic loading on-board navigation system of clearances;
    - On-board detection of wake vortices as a safety net;
    - Airborne wake detection (higher performance);
    - Advanced ADS-B link;
    - Broadcast and reception of aircraft trajectory, weather, and wake-vortex data (ADS-B IN/OUT).

3.3 Flight Planning (Planning Operations)

Planning life-cycle starts with the development of the expected flight plans by the Airspace User and ends with post-flight activities. The trajectory evolves in different development phases (See figure 12):

- Business Development Trajectory (BDT) expresses the intention of the Airspace User. This information is not shared outside the Airspace User organisation. The

managed airspace may be designated for self-separation (eg. above FL450) and the separation provision service will not be given.

process may start several years before the day of operation or in the same day depending on the nature of the Airspace User;

- Shared Business Trajectory (SBT) is made available to the ATM system for planning purposes when the BDT is sufficiently established. During this phase ANSP may adjust airspace organisation to match to the traffic demand and airports will adjust their planning. Potential discrepancies between the SBT and the network constraints will trigger a revision of the SBT by the Airspace User;
- Reference Business Trajectory (RBT) appears just before flight execution and is the trajectory that the Airspace User agrees to fly and the ANSPs and airports agree to facilitate. RBT is the goal to achieve and will be authorised progressively. RBT can change during its execution due to:
  - ❖ RBT automatic update when the predicted trajectory differs from the RBT more than a pre-defined threshold. These thresholds are indicated in the Trajectory Management Requirements (TMR);
  - ❖ RBT revision due to changes in airspace or airports constraints.

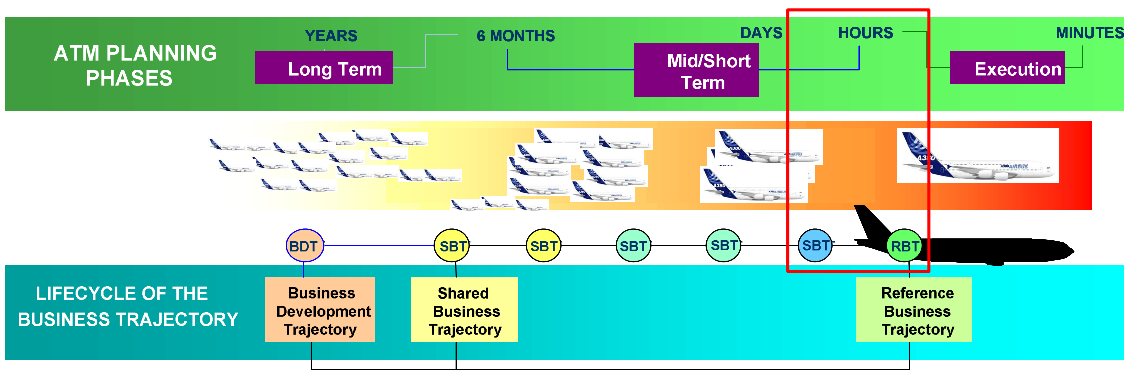

Figure 11 Trajectory Management in the ATM Process

The **Network Operations Plan** (NOP) ensures a common view of the network situation. The NOP is a dynamic rolling plan for continuous operations which draws on the latest available information being shared in the system. The NOP provides access to traffic demand, airspace and airport capacity constraints, scenarios and simulation tools. The most relevant information and functions are:

- Airspace users' intentions through SBTs;
- Agreements, change of resources, trajectory change proposals, etc;
- Using this information the Network Management System facilitates the dialogue and negotiation between partners to solve demand/capacity imbalances;
- If the imbalance persists, the Regional Network Manager will work in close coordination with the Airspace Users, Airports and ANSPs in order to assess the potential delay and define the priorities;
- During short-term planning and execution phase, more accurate information such as weather forecast is available. This will facilitate the decision-making processes.

3.4 Flight execution (Tactical Operations)

Basic flight description:

- SBT becomes an RBT when its times are stable enough;

- The RBT is a conflict-minimised trajectory, not a clearance;
- The RBT will be progressively authorised in the form of successive clearances. These clearances will come from the ANSPs or from the aircraft depending on who is the designated separator. The clearances will include associated Trajectory Management Requirements (TMR).
- Once the RBT is being executed, the aircraft becomes the prime source of information of its own trajectory data. The RBT information is subject to automatic and regular synchronisation with the network;
- Requests to change trajectory may come from ground (due to separation provision, sequencing, weather, changing arrival constraints...) or air. If ground changes are non-tactical changes, ANSP will impose, amend or remove constraints and the user will propose an RBT amendment that meets the constraints;
- If destination airports have capacity constraints, Target Time of Arrival (TTA) will be assigned;
- In high density/complexity airspace AMAN and DMAN will assist to the safely, orderly and efficiently flow of traffic, assigning controlled time of arrival (CTA) to the aircraft as close as possible to the TTA;
- In low and medium density airspace, aircraft will have an Estimated Time of Arrival (ETA). This is not a constraint but provides information about the status of the flight.

Regarding **conflict management and separation modes**, SESAR defines three separation modes categories.

- Conventional modes as today but with better data and tools to improve trajectory and network efficiency;
- Precision Trajectory Clearances (PTC) using the navigational performances of the aircraft, constraint management, and controlled times for queue management purposes. In PTC the aircraft maintains its trajectory within an agreed containment (2D, 3D, or 4D) enabling controllers to manage a significant increase of traffic using supporting tools including conflict prediction and resolution, and conformance and intent monitoring. PTC consists of controller issuing clearances to proceed on a 2D/3D/4D trajectory which is subject to agreement by the flight crew. The clearance is ideally identical to the current RBT or may result in an RBT revision.
- Airborne separation modes using ASAS applications for
  - Cooperative separation, where the role of separator is temporally delegated to the flight crew to assure separation with other aircraft under specific circumstances,
  - Self-separation in which the pilot is the designated separator for a defined segment of the flight during which they shall assure separation from all other aircraft.

This last mode of separation is the one equivalent to A^3 in SESAR. The goal is to allow self-separating flights and ANSP-separated flights operating in the same airspace provided that the target level of safety can be met. Self-separation is expected to be introduced before 2020 in some low density areas to gain experience for broader implementation.

Regarding **collision avoidance**, SESAR will continue the development of ACAS and STCA so that shared information could be used to coordinate warnings and resolution advisories. These advisories will be displayed to both pilot and controller as appropriate. Independent detection logics should be present in the different systems using independent information sources and any available shared sources. Although calculations will be always shared, this does not imply that the two systems would negotiate the resolution manoeuvre.

3.5 Flight Crew: Roles and Responsibilities

Airspace Users responsibilities can be divided in flight crew/pilot and other staff members. The role of the users as owners of the trajectories implies responsibilities in creating, negotiating, adapting, maintaining and distributing them during the planning and execution phases.

Flight Crew:

- To execute the RBT according to required navigational performances;
- To modify RBT (if required);
- To assure separation (if they are assigned as separators) where separation responsibility is assumed by the Flight Crew in accordance with pre-defined rules;
- To avoid collisions;
- To optimize queuing by achieving the assigned RTA.
- For those airlines without an Airline Operational Control such as the General Aviation (GA), the flight crew or the pilot has to plan and submit trajectories' data, or use third parties (AOC, ANSPs or independent companies) for the necessary service support.

Airline Operational Control/Wing Ops:

- To dispatch flights;
- To prioritise flights;
- To develop and plan trajectories;
- To manage Flight data;
- To manage environmental Issues.

Air Navigation Service Providers (ANSPs) will provide services related to the Airspace Organisation and Management, Network Management, Queue Management and Conflict Management. Their mail roles are:

- For the executive, planning, ground and runway controllers, to de-conflict and authorise RBTs, to assure separation and to optimize queues;
- For the Complexity Manager, to assess traffic complexity, to optimise airspace organisation and to modify RBTs;
- For the ATS Supervisor, to manage ATS Resources, to provide Alerting Services and to manage environmental issues;
- For the Air Traffic Safety Electronics Personnel (ATSEP), to provide Communication, Navigation, Surveillance and Information Services and to provide Network services;
- For the MET Data Manager, to provide MET information and to support the trajectory development process;
- For the AI Data Manager, to provide Aeronautical Information and to support the trajectory development process;
- For the SWIM Network Manager (various actors including ANSPs), to provide NOP Access and Services, to provide Network Timing Service and to operate/maintain the SWIM infrastructure;
- For the SWIM Access Manager (various actors including ANSP), to ensure secure access to SWIM Network and to monitor SWIM Access and traffic;
- For the Airspace Designers, to design Airspace for optimum operations and to develop scenarios/simulations for efficient airspace use;
- For the Civil and Military Airspace Managers, to co-ordinate airspace requirements, to provide optimum airspace availability and to publish airspace allocation;
- For the Regional Network Manager, to match overall capacity to demand in planning phase, to develop scenarios/simulations for efficient regional traffic flows, to

coordinate and maintain NOP, to coordinate the management of unexpected events and to provide solutions for continued demand and capacity imbalance;
- For the Sub-regional Network Manager, to match sub-regional capacity to demand in planning phase, to develop scenarios for efficient sub-regional traffic flows and to optimize traffic flow through CDM in Execution phase;

3.6 Communications and supporting systems

Information exchange with certain level of quality is one of the pillars of SESAR. This exchange will be supported mainly through two infrastructures: SWIM (Ground System) which represents the ground and ground-air infrastructure and ADS-B (Airborne System) which supports the air-air communications. In both cases the information could be exchanged by point-to-point data transfer or by broadcasting data.

3.6.1 Ground Systems

SWIM will support Air-Ground and Ground-Ground communications allowing exchange of data and ATM services across the whole European ATM system. SWIM services will need to comply with potentially stringent Quality of Service parameters such us integrity, availability, latency, etc.

The information provided by SWIM can be organised around 6 data domains:
- Flight Data;
- Aeronautical Data;
- Meteorological Data;
- Air Traffic Flow Control management (ATFCM) Scenario Data;
- Surveillance Data,
- Capacity and Demand Data.

The exchange of this information with aircraft will be performed using datalink taking into account the inherent constraint of the Air/Ground datalink. The aircraft will have a single point of access to the ground part of the SWIM architecture with **filtering of the shared information that is needed by the aircraft**. Meteorological, aeronautical, flight data (constraints and clearances) and surveillance data will be uplinked and downlinked.

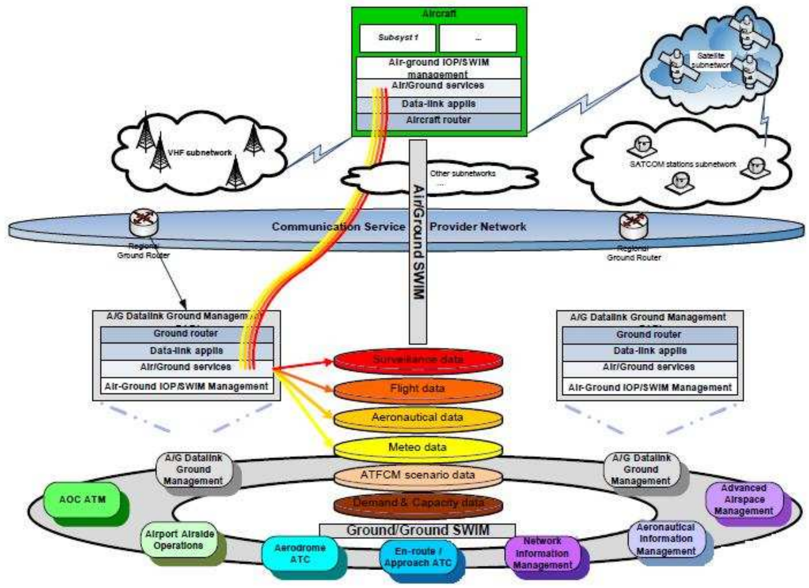

Figure 12 Aircraft in SWIM

3.6.2 Cockpit Systems

Air-to-air communications will allow exchanging information regarding meteorological data, aircraft status and aircraft intention. For that, the subsystems of communication, navigation, and surveillance of the cockpit will be improved. Direct air-to-air exchange of information will support Air Traffic Situational Awareness (ATSAW), ASAS Spacing and separation, and ASAS self-separation.

The main expected functional changes in the aircraft capabilities are:

- Development of a new Flight Manager and Flight Guidance to support 4D trajectories and special approaches. The system will include new functions such as improved 4D prediction algorithms using enriched meteorological modelling, Trajectory Management Requirement (TMR), conformance monitoring, lateral, altitude and longitudinal containment along a segment of RBT, and ASAS spacing, separation and self-separation;
- Development of an air-to-air position and vector exchange to support the previous functions;
- Improvement of airborne surveillance sub-systems such as the Clear air turbulence (CAT), CumulonimBus (CB), Wake Vortices...

When the aircraft is the designated separator, the following capabilities should be available:

- Aircraft will have the capability to exchange data between ASAS aircraft and render the aircraft 'visible' to the ATM system;
- The self-separating pilot will 'validate' successive segments of the trajectory ahead of the aircraft - analogous to successive clearances by a controller -;
- The objective for ASAS self-separating aircraft will be to adhere to the RBT. The aircraft will return to the RBT when a conflict is solved;

- Execution of separation tasks involving ASAS aircraft will be supported by high levels of automation and procedures and will be initiated at the system-system level i.e. no manual task for the pilot under nominal circumstances;
- When self-separating from aircraft under controller separation, the ASAS aircraft is responsible for executing any required separation manoeuvre.

Air-to-air surveillance will be based in ADS-B in/out applications to support ATSAW and ASAS spacing. For ASAS self-separation, a high performance data link is requested to improve the air-air data capacity, integrity, security and availability.

3.7 Similarities & Differences between A^3 ConOps & SESAR2020 ConOps

The key elements of the A^3 and SESAR ConOps have been described in previous sections in order to facilitate the identification of similarities and trade-offs between both concepts.

An important issue to highlight is that the SESAR ConOps is described in higher level than the A^3 ConOps. SESAR Operational requirements will be further refined within each individual Sesar Joint Undertaking (SJU) project, and consequently the level of detail will be more in line with iFly.

A brief summary clarifying the main differences and similarities between SESAR and A^3 concepts are illustrated in the following table:

		Similarities	Differences
Airspace & Zones		• Restricted airspace Areas • No fixed routes[19]	• A^3: New airspace defined (SSA) • A^3: New definitions of zones for possible implementations of separations minima, meteorological data communications, surveillance and awareness zones
Key Enablers		• SWIM • CDM • Advanced Airborne Systems	• A^3: Preliminary considerations of SSEP-specific high-level functional requirements
Flight Planning		• RBT based	• A^3: Different metrics for SSA planning (no ATCo, no sectorization)
Flight Execution		• Airborne self-separation for merge and fly behind each other	• A^3: Analysis of new operational and functional requirements on on-board systems • A^3: CD&R described in detail (not in SESAR so far)
Flight Crew: Roles and Responsibilities		• Responsible for the operation of the flight	• A^3: responsible for separation (additional tasks) • SESAR: responsible for separation only if delegated
Communication and supporting systems	**Ground Systems**	• Based on SWIM • Data link	• A^3: New targeted SWIM-based services regarding MTLZ and LTAZ are described
	Cockpit Systems	• New requirements for on-board systems to support proper operations will be needed	• A^3: Preliminary system considerations

[19] SESAR2020 ConOps, could allowed to use fixed routes at the proximity of specific busy TMA

A^3 has several similarities and differences with SESAR. The main differences are related to the roles and responsibilities of the ATM actors. In the A^3 ConOps flight crew is the sole responsible and the figure of the controller disappears while in SESAR the controller maintains the separation assurance responsibility.

The main difference regarding the ATFCM processes is the required information to take decisions on regulations. Additionally, the information provided by SWIM to support operations is another point of difference.

Regarding similarities, both concepts are supported by information such as environmental data, trajectory data and aircraft data. Information exchange is supported by SWIM and by data link (Air-Ground and Ground-Ground communications) in both environments.

Another main similarity is that planning phase of the flight is based on RBT. On flight execution, self-separation is performed the same for merging but in the A^3 environment all the responsibility and conflict detection and resolution are on-board.

4 Options to incorporate A^3 equipped aircraft within SESAR 2020 ConOps

The operational implementation of new Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) capabilities is a complex and long process. Differences in the implementation timeframe of the involved stakeholders slow down the process.

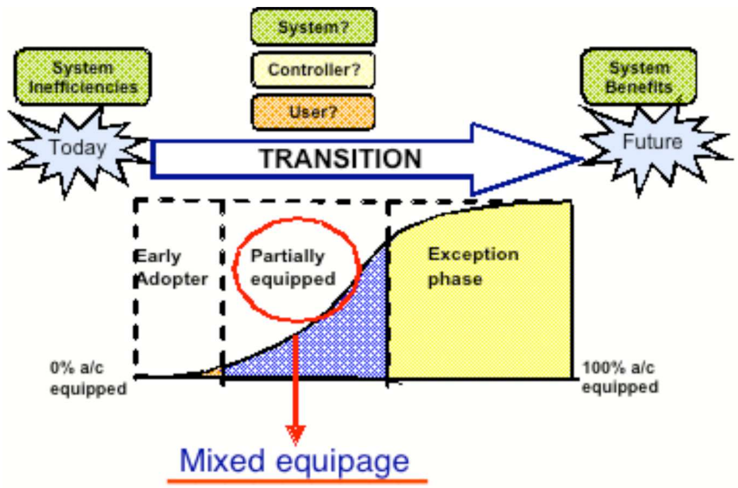

Figure 13 SESAR Transition

This section provides options about how A^3 equipped aircraft can be incorporated in the SESAR 2020 ConOps. Due to the nature of the A^3 operations, it is assumed that all aircraft are A^3 equipped. However, at best a gradual increase of A^3 equipped aircraft will be the case. Section 4.1 describes the main ATM issues regarding the gradual increase of A^3 equipped aircraft within SESAR.

Four different approaches or solutions to the gradual integration of A^3 aircraft within SESAR 2020 environment are proposed and further explained in the next sections:

- Exclusionary[20] airspace, in which only A^3 equipped aircraft will be allow operating, This Exclusionary Airspace is defined within the en-route airspace and above a certain FL limit (See Section 4.2);
- Airspace corridors, in which Non- A^3 equipped aircraft will operate (See Section 4.3);
- Full use of A^3 equipment in Non-exclusionary Airspace, where A^3 equipped and Non- A^3 equipped aircraft are permitted with some restrictions or constraints (See Section 4.4);
- Partly use of A^3 equipment in Non-exclusionary Airspace, where A^3 equipped and Non- A^3 equipped aircraft are permitted with A^3 aircraft using only part of their capabilities (See Section 4.5).

[20] Adj-exclusion, the act or an instance of excluding or the state of being excluded.

4.1 ATM issues to be considered

Strategic ATM issues to gradually incorporate A^3 equipped aircraft within the SESAR 2020 environment are explained in the following sections. These issues are the basis for the analysis of the different proposed solutions (sections 4.2-4.5).

Mixed equipage

Mixed equipage refers to the coexistence of aircraft with various equipments and capabilities subject to different operating procedures in the same airspace. Mixed equipage comprises mixed technical equipment which enables different operating capabilities.

Achieving significant benefits from the operation of autonomous aircraft depends upon the high percentage of equipped traffic. In any case, the proposed integration solution must be able to provide benefit with only a portion of aircraft fully equipped.

Apart from the flight efficiency, human factors aspects need to be addressed when aircraft with different equipment are operating. During the first stages of the transition, a mixed environment may increase complexity or reduce situational awareness.

4D ATM including a systematic way of working with uncertainty

Business trajectories will be expressed in all 4 dimensions (position and time). Thus, aircraft will fly with higher precision than today. Sharing unique and accurate 4D trajectory information will reduce uncertainty and will give all stakeholders a common reference. This will improve collaboration across all organisational boundaries.

The aircraft becomes the prime source of trajectory information once the RBT is being executed by the aircrew. The RBT is subject to automatic and regular synchronisation through the RBT automatic update processes. On-board systems will guide the aircraft along the cleared trajectory.

Integrating ATFM

There is a need of ensuring a common view of the network situation thanks to a dynamic rolling plan for continuous operations instead of a series of discrete daily plans . This dynamic rolling plan will be based on the latest available information being shared in the system.

The system should work with a set of collaborative applications providing access to traffic demand, airspace and airport capacity and constraints, pre-defined scenarios to assist in managing diverse events and simulation tools for scenario modelling. The aim is to facilitate the DCB processes by means of collaborative-decision making tools.

Long-term ATM planning starts with traffic growth forecasts, including users' business strategies and planned aircraft procurements. The required new assets can be considered as available resources for DCB only when their date of delivery becomes firm. Airspace Users will then declare their intentions through Shared Business Trajectories possibly including the requirements for airspace reservations. Sub-regional and Regional Network Manager, working collaboratively with all partners, will assess the resources situation with regards to the demand. Network Management processes will facilitate dialogue and negotiation to resolve demand/capacity imbalances in a collaborative manner. Tools will be used to assess network efficiency.

CDM & demand management

The RBT is the core of the system in both the SESAR 2020 and the A^3 ConOps. The aim is to execute each flight as close as possible to the users' intentions. Consequently, this is changing the focus from airspace to trajectory management.

Business trajectory lifecycle starts with the development of the expected flight plans by the Airspace User and ends with post-flight activities.

A Collaborative Decision Making (CDM) process is in place in which all stakeholders share the necessary information to ensure the long and short-term stability and efficiency of the ATM network and to ensure that the necessary ATM services can be delivered on the day of operation.

Human roles and responsibilities

Human operators (with appropriate skills and competences, and duly authorised) will constitute the core of future European ATM System. However, an advanced level of automation will be required to accommodate both the expected traffic increase and the reference level of performances.

Human roles and tasks within the future system will necessarily change as a consequence of the automation. This will affect system design and evaluation, staff profiles, training (especially for unusual situations and degraded modes of operation), competence requirements and relevant regulations. The development of the future ATM network can only succeed if humans are understood as a part of "the ATM system", ensuring performances in a complex interaction with procedural, system, organisational, institutional and cultural aspects.

System Wide Information Management (SWIM)

System Wide Information Management (SWIM) supports the entire ATM system and is essential to guarantee the efficiency of the operations. SWIM is a net-centric system that is built upon multiple nodes providing or consuming information (including the aircraft). SWIM will support collaborative decision making processes, using efficient end-user applications to exploit the power of sharing information.

SWIM is supported by a set of architectural elements (so-called SWIM architecture) allowing exchange of data and ATM services across the entire European ATM system. SWIM is based on the interconnection of various automated systems. The SWIM architecture aims at providing specific information management services in order to support flexible and modular sharing of information, as opposed to closely coupled interfaces. SWIM provides transparent access to ATM services and assures the overall consistency.

SWIM services will be required to comply with potentially stringent Quality of Service (QoS) parameters such as integrity, availability, latency, etc.

SWIM integrates Air-Ground and Ground-Ground data and ATM services exchange. All ATM relevant information such as trajectories, surveillance data, aeronautical information and meteorological data is managed through SWIM.

4.2 Exclusionary airspace

This section explains the first option for the transition phase from SESAR to the A^3 environment with different equipped aircraft coexisting at the same time.

The Exclusionary Airspace is an area where only A^3 equipped aircraft will be allow operating. These aircraft will fly following Autonomous Flight Rules (AFR). Airspace users will be responsible for separation assurance within that airspace.

This area is defined within the en-route airspace and above a certain Flight Level. Below this specific Flight level, only Non- A^3 equipped aircraft will be allowed. They will fly in a SESAR Managed Airspace (MA) and according to the IFR rules defined in SESAR. ANSP will be the re-determined separator.

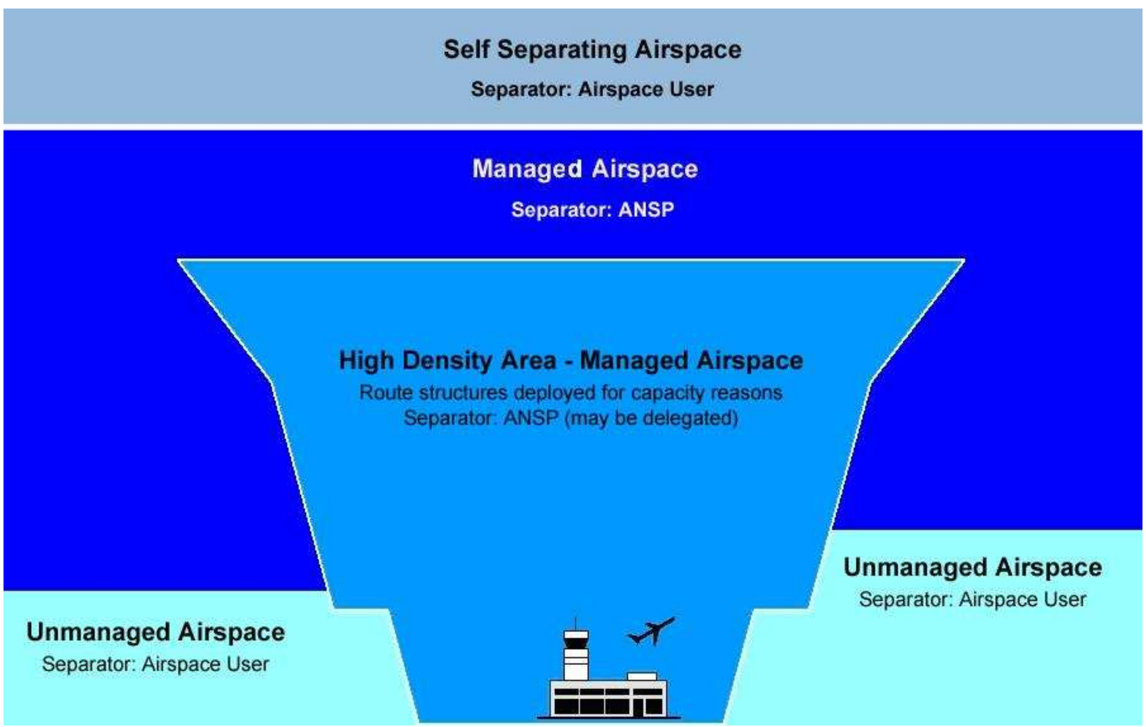

Figure 14 Exclusionary Airspace

A gradual increase of A^3 aircraft will imply more Exclusionary Airspace (SSA) and a progressive decrease of Managed Airspace (MA) until the whole airspace will become SSA .

The following paragraphs provide further analysis of this solution and the key issues for SESAR:

Mixed Equipage

The use of Exclusionary Airspace above certain Flight Level implies that although aircraft with different equipments and capabilities will coexist, they will not operate using different operating procedures in the same airspace.

A^3 equipped aircraft out of the exclusionary airspace will be separated by ATCos. The processes to enter and exit this airspace will be similar to the one defined in the A^3 ConOps for aircraft reaching TMA.

This segregation will avoid the need of new equipage both in A^3 and non-A^3 equipped aircraft.

4D ATM including a systematic way of working with uncertainty

A^3 aircraft will be able to plan and follow 4D trajectories with a high degree of precision. This will reduce the problems in the boundary between Exclusionary and SESAR Managed Airspace. ATCos will be able to analyse the part of the RBT in the Managed Airspace with sufficient time in advance. Entry controlled times will be issued with minimum impact to the planned trajectory.

Integrating ATFCM

ATFCM processes will prioritize the A^3 equipped aircraft, providing operational advantages in the planning phase and also during the execution of the flight. This will encourage the Airspace Users to invest on the necessary equipage.

Flow management will manage the controlled time to enter/exit the SESAR Managed Airspace in order to optimize flows at the planning phase.

CDM & demand management

CDM will be equally performed as in A^3 general concept with the only difference that the part that is subject to ANSP capacity restrictions is wider than just the TMA.

Additionally to the CTA, another time should be defined by CDM process to entry the Managed Airspace. This entry controlled time will facilitate conflict-free operations in the immediate vicinity of the entry points.

Human roles and responsibilities

Automation is responsible for conflict detection and resolution above the designated FL. Thus, the flight crew is the sole separator and its role will be aligned with the A^3 ConOps (See 2.5). Consequently, ATCos play no role in the SSA environment.

Automation continues playing an outstanding role below the designed Flight Level, but in this case ATCos are responsible for the separation provision.
Under MA operations, below the designated FL, automation continues to play an outstanding role, but in this case it is under the service of the controller who is responsible of separation

provision. Flight crew is now responsible for the execution of the RBT according to the required navigational performance, optimization of queues by achieving the assigned RTA and collision avoidance. On the contrary. They are not responsible for assuring separation (See 3.5).

System Wide Information Management (SWIM)

SWIM will be able to provide the services related to A^3 equipped aircraft in the exclusionary Airspace, and the ones related to non-A^3 equipped aircraft in the Managed Airspace. This duplication of services increases the complexity of the system given that double service in the A^3 ConOps is only provided in the airspace surrounding the TMA.

Main Conclusions

The main considerations about the feasibility of this solution are:

- The main advantage of the Exclusionary Airspace is that provides a more homogeneous operating environment and less variation than in a mixed equipped environmental in roles and responsibilities for human operators. This will reduce the potential risks during off-nominal events[21] and will reduce the expected workload and lack of situational awareness of the main actors during normal operations;
- Efficient segregated airspace may encourage users to invest in advanced equipage[22]
- Segregating the airspace is an alternative to reduce complexity through the use of two quasi-homogeneous groups, thereby, mitigating the likelihood of human errors and improving safety;
- The early use of this type of segregation will help in the refinement of A^3 concept and procedures;
- Segregating airspace may increase costs related to the underutilization of airspace capacity. In addition, segregation may reduce the users' flexibility because some aircraft cannot access part of the airspace. This could be especially problematic in case of bad weather conditions or other flow restrictions;
- Segregation of airspace is costly. Autonomous aircraft may individually improve their costs by a better adherence to their RBT, but certain services should be duplicated for assuring the operation in both airspaces,
- This proposed solution is based on approaches already implemented such as the reduction in channel spacing VHF from 25 kHz to 8.33 kHz in European sky[23]. 8.33 kHz was introduced above FL245 in the ICAO EUR Region from October 1999 and above FL195 from the 15 March 2007.

4.3 Airspace Corridors

[21] Non-nominal events are out of the scope of A^3 ConOps

[22] L. Forest & R. J. Hansman, "The Future Oceanic ATC Environment: Analysis of Mixed Communication, Navigation, and Surveillance Equipage, " *ATC Quarterly, V14 (2)*, 117-138, 2006.

[23] http://www.eurocontrol.int/vhf833/public/subsite_homepage/homepage.html

The second proposed option for the transition phase between SESAR and a fully compliant A^3 environment is to define airspace corridors. Two different alternatives are proposed depending on the percentage of A^3 equipped and non-equipped aircraft:

- Managed Airspace Corridors in a Self Separating Airspace. Non-A3 equipped aircraft fly in the corridors with the ANSPs as the pre-determined separator. These corridors will be located between Terminal Areas. Aircraft flying inside will not be permitted to leave the corridors;
- SSA Corridors in a Managed Airspace. Corridors for SSA are enabled within the Managed Airspace.

Corridors are similar to "holes" inside the airspace with horizontal and vertical boundaries. These corridors can also be lanes to facilitate crossing.

Corridors can be static or dynamic. Corridors may be dynamically shifted, only utilize during certain times of the day or in response to certain triggers. The corridor's length may also stretch or shrink during the day to accommodate more or less traffic. Also static corridors could be available depending on the number of flights that will use them along the day of operation.

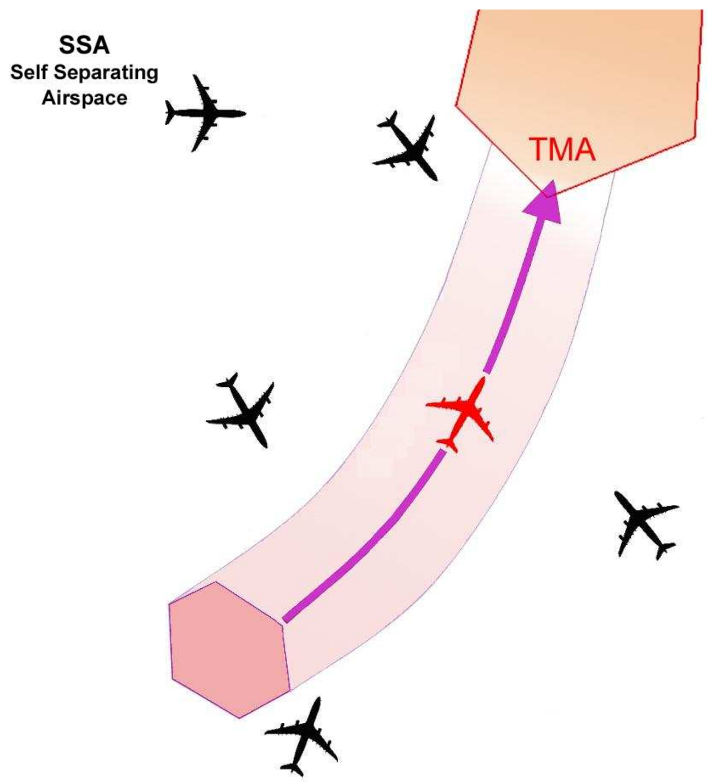

Figure 15 Airspace Corridors, option MA corridors in SSA airspace

Figure 16 shows the case of MA corridors in SSA airspace. The number of corridors will be gradually decreased according to the progressive reduction of the number of non-A^3 equipped aircraft. Static corridors could be a feasible solution when the percentage of non-A^3 equipped aircraft is high. Dynamic corridors will be a better solution if the number of non-A^3 equipped aircraft is reduced.

SSA Corridors in Managed Airspace may promote the upgrade of fleets, given that they will be used as high-speed routes for the main flows. Aircraft would follow A^3 equipped aircraft when inside SSA corridors. Aircraft would be able to enter and exit the corridors according to their flight plan. An increase of A^3 equipped aircraft may lead to a change to the first solution, establishing corridors for MA corridors in SSA Airspace.

The following paragraphs provide further analysis of this solution and the key issues for SESAR:

Mixed equipage

Although autonomous aircraft and ATCo-controlled aircraft will coexist in the same airspace volume, there will be a "physical" barrier that separates both environments.

Corridors will be introduced as restricted areas (RAA) in the A^3 FMS. These corridors will be deployed minimising the impact on A^3 operations (for the first option) or maximizing the operational gain (for the second option). Thus, detailed assessment regarding the number and position of these corridors should be carried out during the planning phase. This will allow activating the corridors when needed and deactivating when unused.

In TMA areas and in the Managed Airspace, the separation provision for A^3 aircraft will be provided by ANSPs.

4D ATM including a systematic way of working with uncertainty

In this scenario, the uncertainty associated to the performance of the 4D trajectory would mainly impact the aircraft within the corridors. Nevertheless it is expected that at the timeframe when this measure is adequate to be deployed, aircraft will have a performance accurate enough to avoid crossing the corridor barriers unexpectedly.

Uncertainty could have an impact on the size and number of corridors needed.

Integrating ATFCM

Methodologies are needed to dynamically compute the topology of the corridors in the planning phase. The number of non-A^3 equipped aircraft and their user-preferred trajectories will determine the optimal corridors structure, size, activation/deactivation times, etc.

The flight plans of A^3 equipped aircraft will indicate the entry and exit points to the corridor in case of SSA corridors.

ATFCM rules to dynamically add or remove corridors are needed in order to optimize the traffic flows.

CDM & demand management

Demand management will be treated differently for A^3 aircraft and non-A^3 aircraft. A^3 aircraft will be prioritised in the CDM processes where both types of aircraft coexist (TMA airspace).

Regulations due to sector overload could be used inside the MA corridors. In addition, ATFCM will activate/deactivate dynamically corridors to facilitate the management of the demand.

Human roles and responsibilities

Automation is responsible for conflict detection and resolution under the SSA operations outside TMA and designated MA corridors. Thus, the flight crew is the sole separator and is responsible of avoiding MA corridors and other restricted areas.

Automation continues playing an outstanding role under MA operations inside TMA and designated MA corridors. In this case, the ATCos are responsible for the separation provision. Flight crew is now responsible for executing the RBT according to the required navigational performance, optimizing queues by achieving the assigned RTA, and avoiding collisions.

System Wide Information Management (SWIM)

SWIM will be able to provide the services related to A^3 equipped aircraft in the whole airspace, and those services related to other modes of operation in the corridors and Managed Airspace. Thus, no difference in the SWIM requirements are foreseen with respect to the previous option.

All information about corridors must be introduced in the system and it be available for all involved actors.

This option is based on a NextGen[24] concept named "flow corridors" for the super dense traffic conditions typically experienced in the terminal areas. This idea was first gathered on the Eurocontrol Programme EATCHIP[25] (European ATC Harmonisation and Integration Programme).

4.4 Full use of A^3 equipment in Non-exclusionary airspace

The third proposed option for the transition into a fully compliant A^3 environment is to define a non-exclusionary airspace. A non-exclusionary or integrated Managed Airspace is defined as an airspace where both non-A^3 equipped aircraft and A^3 equipped aircraft are allowed.

A^3 equipped aircraft will self-separate but the non-A^3 equipped aircraft will be separated by the ANSPs.

A^3 equipped aircraft flight crew will be responsible for separating their aircraft from all other aircraft including non-A^3 equipped aircraft. ANSPs will only be responsible for non-A^3 equipped aircraft.

[24] For more information see iFly Deliverable D1.3 Autonomous Aircraft Advanced (A3) ConOps

[25] EATCHIP therefore evolved into EATMP, the European Air Traffic Management Programme. http://www.eurocontrol.int

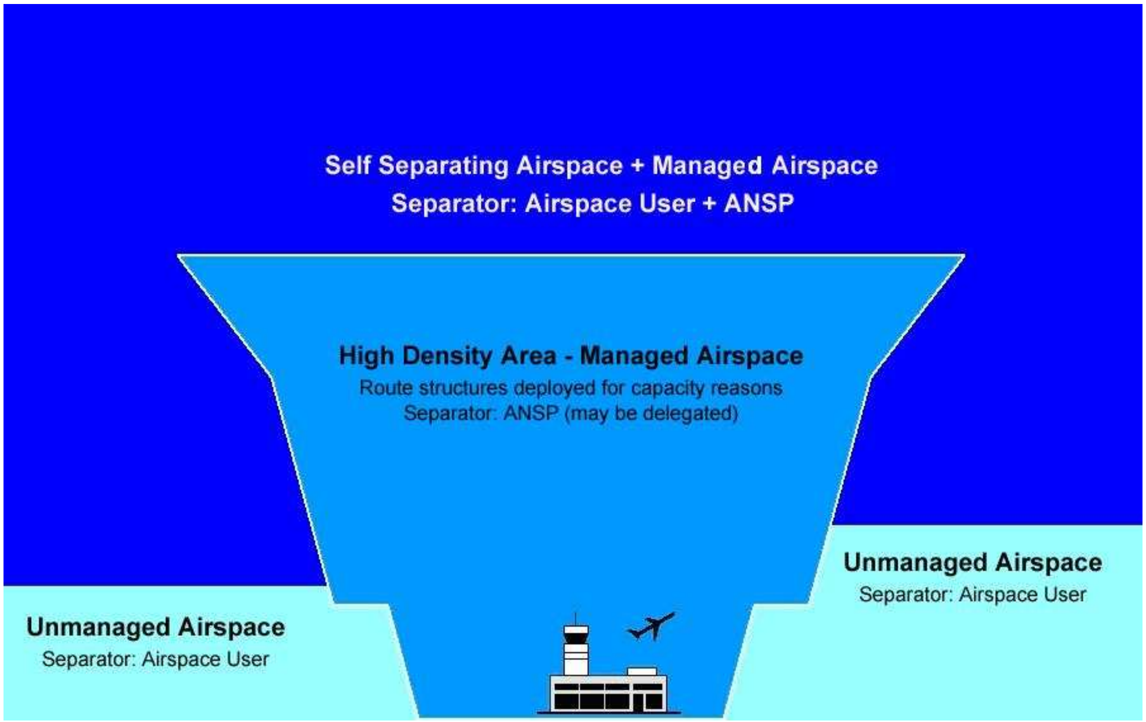

Figure 16 Full use of A^3 equipment non –exclusionary airspace

The definition of new rules is a key issue. Autonomous rules (AFR) are still valid between A^3 equipped aircraft but not for SESAR equipped aircraft. Hence new rules for the interaction between operations involving mixed aircraft will be needed.

A^3 equipped aircraft are expected to resolve all conflicts in which they are involved. Conflicts between non-A^3 equipped aircraft will be solved by the controllers. Conflicts between A^3 equipped and non- A^3 equipped aircraft will be announced to the controllers only if the A^3 equipped aircraft flight crew cannot solve the conflict (controllers can contact the pilot to coordinate a solution). Pilots or controllers cannot make any change causing a predicted LoS in short-term.

With the gradual increase of A^3 equipped aircraft, the non-exclusionary airspace will become more and more “autonomous” and less participation of ANSP will be needed.

This option where airspace usage is shared by both types of aircraft has a limited application. A recent study [26] has identified a limit related to the percentage and number of each type of aircraft that controllers can assume with a manageable workload. This maximum depends on several complexity factors such as non-A^3 equipped traffic density in the sector.

Another consideration is the possibility of changing current controller’s procedures by the implementation of new concepts that may improve controller’s performance in this

[26] Kopardekar, P., Smith, N., Lee, K., Aweiss, A., Lee, P., Prevot, T., Mercer, J., Homola, J., and Mainini, M., “Feasibility of Mixed Equipage Operations in the Same Airspace,” Eighth USA/Europe Air Traffic Management Research and Development Seminar, Napa, California, June 2009.

environment. One concept under study is the sector-less air traffic management[27] where controllers manage the entire trajectory of several non-A^3 equipped aircraft in an airspace (ideally from TMA to TMA) instead of all the aircraft in one sector.

The following paragraphs provide further analysis of this solution and the key issues for SESAR:

Mixed equipage

Aircraft with different equipment and capabilities will coexist and operate using different procedures in the same airspace.

The end-state of SESAR foresees an environment with self-separated aircraft, free-route aircraft separated by ANSPs and aircraft following route structures separated by ANSP in the same airspace.

New equipment will be needed for flight crews and controllers. This equipment will support the detection and resolution of conflicts involving A^3 equipped and non-A^3 equipped aircraft following certain rules specifically defined. As explained above, A^3 equipped aircraft will manoeuvre to solve this type of conflicts. Nevertheless a protocol to contact controllers and negotiate other solutions will be defined to take into consideration all potential manoeuvres of the A^3 equipped aircraft that could produce a LoS in the short-term. Another protocol will be established for controllers to contact A^3 equipped aircraft for situations where the only viable manoeuvres for the non-A^3 equipped aircraft will produce a LoS with an A^3 equipped aircraft.

4D ATM including a systematic way of working with uncertainty

Non-A^3 equipped aircraft will have different capabilities which will provoke different levels of uncertainty associated to the performance of the trajectory. Studies should be performed to define the best approach to model this uncertainty in the different systems taking into account safety, cost- effectiveness and capacity.

One option is to associate a level of uncertainty to each flight according to its capabilities. Another alternative is to use the most penalising uncertainty associated to an aircraft. There could be also several groups of aircraft in different categories of uncertainty.

Integrating ATFCM

ATFCM processes will prioritize the A^3 equipped aircraft, providing operational advantages in the planning phase and also during the execution of the flight. This will encourage the Airspace Users to invest on the necessary equipage.

CDM & demand management

The sector capacities provided by the ANSP may make necessary the activation of CDM processes among the airspace users. A^3 equipped flights will also be subject to this capacity

[27] Duong, V., Gawinowski, G., Nicolaon, J.-P. & Smith, D.,"Sector-less air traffic management", 4 th USA / Europe Air Traffic Management R&D Seminar, 2001

limits as the controllers will have to take them into consideration under specific conditions (see next section human roles and responsibilities).

Human roles and responsibilities

Automation is responsible for conflict detection of all aircraft under the integrated airspace operations. The flight crew is responsible for the separation of A^3 equipped aircraft. The ANSPs are responsible for conflict resolution of non-A^3 equipped aircraft.

A^3 equipped aircraft separation is not under ATCos' responsibility but they need to be aware of their location and planned trajectories, given that they need to consider the A^3 equipped traffic before instructing a non-A^3 equipped aircraft to change its trajectory. Also controllers should be aware of short-term non-A^3 equipped/A^3 equipped aircraft conflicts. Consequently the main changes in their roles are summarized as follows:

- A^3 equipped aircraft separation is not under their responsibility;
- Avoidance of short-term conflicts with A^3 equipped aircraft;
- Minimization of medium and long-term conflicts with A^3 equipped aircraft;
- Detection of short-term non- A^3 equipped / A^3 equipped aircraft conflicts;
- Do not move the involved non- A^3 equipped aircraft if you see a conflict with an A^3 equipped one, unless contacted

Flight crew will be aware of all other surrounding aircraft and they will resolve conflicts between A^3 and non-A^3 equipped aircraft. They will contact the ANSPs if a conflict with non-A^3 equipped aircraft cannot be solved in the short-term.

Controllers will change significantly their responsibilities and role. Consequently, training will be a key issue to prevent the impulse of moving the aircraft under their responsibility and create a conflict involving A^3 equipped aircraft.

Automation is responsible for conflict detection of all aircraft under the integrated airspace. Automation is responsible for conflict resolution of those aircraft that are equipped or capable of being supported by such automation. The controller is responsible for conflict resolution of those aircraft that are not equipped to support the automated separation.

System Wide Information Management (SWIM)

SWIM will allow providing the services related to A^3 equipped aircraft and non-A^3 equipped aircraft in the whole airspace. SWIM will also be able to clearly identify the different types of operations and distribute this information to all the involved actors.

4.5 Partly use of A^3 equipment in Non-Exclusionary Airspace

The fourth proposed option is to define a non-exclusionary airspace where A^3 equipped and Non-A3 equipped aircraft are permitted with A^3 aircraft using only part of their ASAS capabilities. Medium-term conflict detection and resolution will be performed by controllers. Aircraft could fully use their ASAS capabilities to commit with their RBTs, enabling the flight crew of the A^3 equipped aircraft to take tactical decisions just in case of short-term conflicts [7]. Thus, A^3 equipped aircraft do not use their own conflict-free trajectory generation capabilities. They accept solutions received by the ATCos, and only in case of short-term conflicts, A^3 equipped aircraft may propose solutions, and the controller is the last responsible for selecting the best solution.

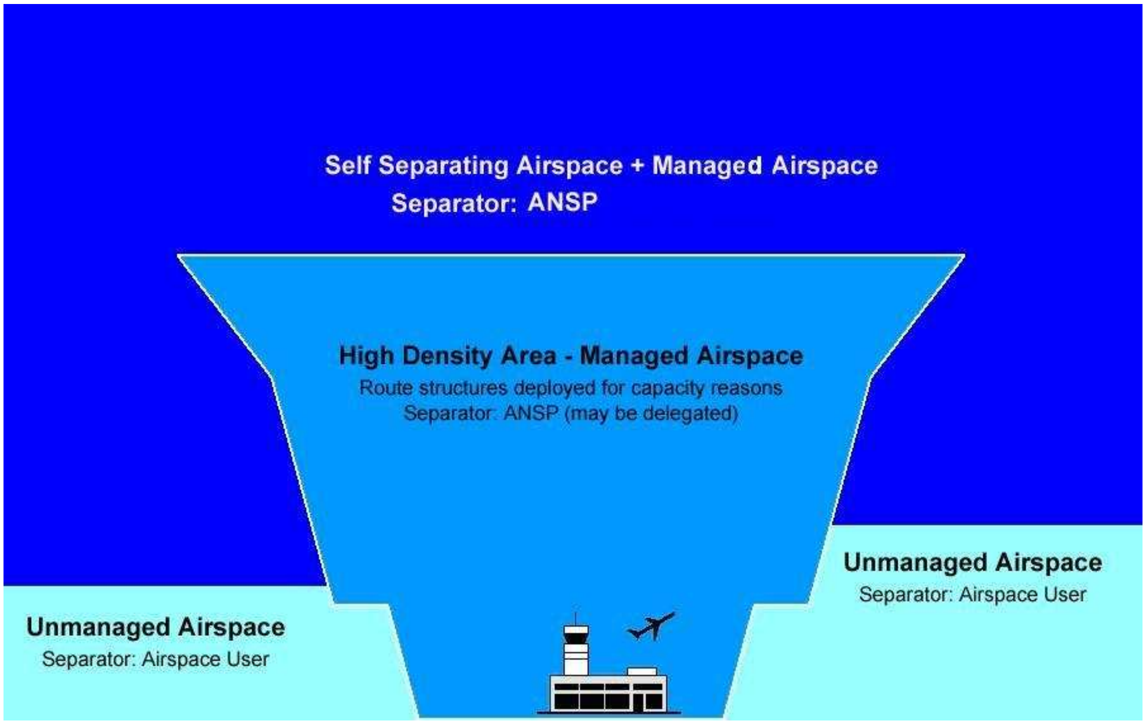

Figure 17: Partly use of A^3 equipment non –exclusionary airspace

The following paragraphs provide further analysis of this solution and the key issues for SESAR:

Mixed equipage

Approach aircraft with different equipment and similar capabilities (both aircraft with ASAS) will coexist and operate using similar procedures in the same airspace.

The operative equipment will be similar in both types of aircraft. The ASAS equipment will propose solutions only in short-term.

In the case of short-term conflicts, the A^3 equipped aircraft coordinate the potential resolution with the ATCos, but they will remain as the final decision for the separation.

4D ATM including a systematic way of working with uncertainty

Different aircraft capabilities between A^3 and non-A^3 equipped aircraft will coexist in the same airspace. This will lead to different levels of uncertainty in their expected trajectories.

Integrating ATFCM

ATFCM processes will prioritize the A^3 equipped aircraft, providing operational advantages in the planning phase and also during the execution of the flight. This will encourage the Airspace Users to invest on the necessary equipage.

CDM & demand management

Both types of aircraft will negotiate following the constraints coming from the sector capacity limits.

Human roles and responsibilities

Although A^3 flight crew will be aware of all other aircraft, the resolution of a conflict with a non-A^3 equipped aircraft falls under the tasks of the air traffic controller. Hence, ANSPs will be responsible of conflict resolution for all encounters involving non-A^3 equipped aircrafts.

A^3 flight crew will change their role given that the conflict resolution is under the responsibility of the ANSPs for all type of conflicts.

System Wide Information Management (SWIM)

SWIM will allow providing the services related to A^3 equipped aircraft and non-A^3 equipped aircraft in the whole airspace. SWIM will also be able to clearly identify the different types of operations and distribute this information to all the involved actors.

5 Concluding remarks

The A^3 ConOps [D1.3] has several similarities and differences with the SESAR 2020 ConOps (section 3). The main differences are related to the roles and responsibilities of the ATM actors. The flight crew is the sole responsible for separation provision in the A^3 concept of operations, and consequently the figure of the controller disappears. On the contrary, in SESAR the controller keeps the responsibility for separation assurance although delegation to the flight crew is temporary allowed under certain conditions.

Both concepts consider the need of a dynamic demand and capacity balancing process supported by collaborative decision-making in order to create a dynamic rolling plan which is progressively adapted to the airspace constraints. ATFCM in both concepts monitors the overall network. The main difference in the ATFCM process is related to the required information to issue the regulations. Additionally, the information provided by SWIM to support the daily operations is also another key difference although the architecture does not need to be necessarily different.

In some aspects A^3 can be seen as an evolution of SESAR where the number of aircraft and the level of automation imply that the management of trajectories is more easily performed by the flight crew using on-board avionics than by the ground systems.

The evolution from SESAR to the A^3 Concept of Operations may be performed following a step-by step approach. Different approaches are detailed in the present document, although none of them answer all the issues regarding safety, efficiency, capacity and cost-effectiveness. The approach is explained in section 4.5, *Partly Use of A^3 Equipment in Non-Exclusionary Airspace*, and is completely in line with the SESAR vision given that is similar to the expected transition between nowadays and a full SESAR environment. On the first phase of the transition from a full 2020 SESAR environment, on-ground systems will be responsible for the separation of all type of aircraft. This will progressively evolve towards the A^3 environment. In this case, controllers will continue being the last responsible for separation between all type of aircraft but workload will be reduced by proposing solutions to short-term conflicts.

During the transition phase, A^3 equipped aircraft will be privileged in order to encourage Airspace Users to invest in A^3 equipage for their aircraft, and thus to progressively evolve towards a full A^3 environment.

I Acronyms List

Acronym	Definition
A^3	Autonomous Aircraft Advanced
ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependant Surveillance - Broadcast
AFR	Autonomous Flight Rules
AI	Aeronautical Information
AFO	Autonomous Flight Operations
AMAN	Arrival Manager
ANSP	Air Navigation Services Provider
ASAS	Airborne Separation Assistance System
ATC	Air Traffic Control
ATCo	Air Traffic Controller
ATFCM	Air Traffic Flow Control Management
ATSAW	Air Traffic Situation Awareness
ATSEP	Air Traffic Safety Electronics Personnel
ATM	Air Traffic Management
BDT	Business Development Trajectory
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
CP	Conflict Prediction
CR	Conflict Resolution
CSZ	Comfort Separation Zone
CTA	Controlled Time of Arrival
EGPWS	Enhanced Ground Proximity Warning System
ETA	Estimated Time Arrival
DL	Data Link
DST	Decision Support Tools
FMS	Flight Management System
FOC	Flight Operations Centre
GA	General Aviation
HMI	Human Machine Interface
IFR	Instrument Flight Rules
KPA	Key Performance Area
LoS	Loss of Separation
LTACD	Long Term Area Conflict Detection
LTAZ	Long Term Awareness Zone
MA	Managed Airspace
MET	Meteorological Service
MSL	
MSZ	Minimum Separation Zone
MTAZ	Medium Term Awareness Zone

Acronym	Definition
MTCD&R	Medium Term CD&R
NFU	Non-FOC Airspace User
NOP	Network Operation Plan
NVFR	Night Visual Flight Rules
OI	Operational Improvement
PANS	Procedures for Air Navigation Services
PAZ	Protected Airspace Zone
PTC	Precision Trajectory Clearances
R/T	Radio Telecommunications
RAA	Restricted Airspace Area
RBT	Reference Business Trajectory
RNP	Required Navigation Performance
RTA	Required Time of Arrival
SA	Situational Awareness
SBT	Shared Business Trajectory
SESAR	SES Advanced Research
SFM	Strategic Flow Management
SSA	Self Separating Airspace
SSEP	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
TA	Traffic Alert
TBD	To Be Defined
TCAS	Tactical Collision Avoidance System
TCP	Trajectory Change Point
TIS-B/C	Traffic Information Service-Broadcast/contract mode
TMA	Terminal Area
TMR	Trajectory Management Requirements
TS	Trajectory Synthesizer
TTA	Target time of Arrival
UA	Unmanaged Airspace
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
WHA	Weather Hazard Areas

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