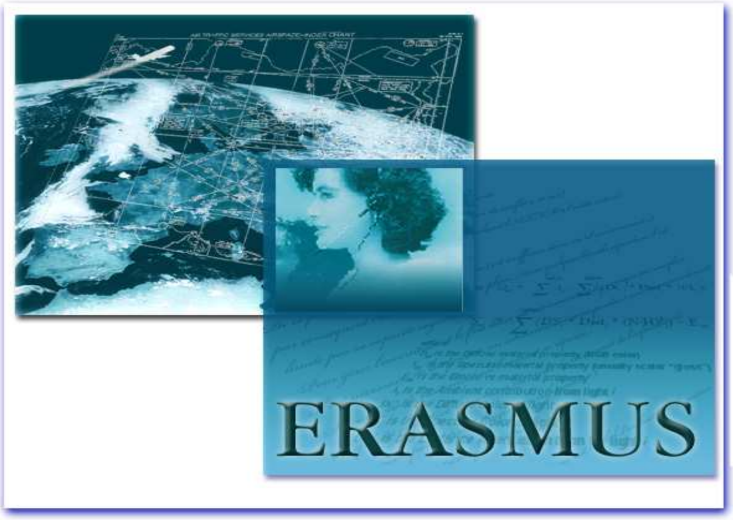
PRIORITY 4 - AERONAUTICS AND SPACE



ERASMUS - Concept of Operations

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Executive summary

(1) Air traffic is expected to triple by 2025. However, the current air traffic management system is very close to its functional capacity and does not yet take advantage of modern automation that could accommodate the expected traffic increase.

(2) The future concepts of SESAR and NGATS propose to build a predictive baseline system complemented with abnormal situations recovery functions. The qualitative treatment of the traffic is achieved by setting down a set of requirements on the absolute future positions of each flight with the flow, or furthermore, on the relative positions of the flights within the flow respecting the schedule and routing requirements expressed in the flight plan and this before the departure of the flight.

(3) The expected benefits are first, the respect of flights adherence to schedule, second, a reduction of the sector traffic complexity. The technical model supporting theses concepts is built on time-ordered architecture that manages the set of operational plans, theirs issues, distribution and updates throughout time, taking advantages of a much more extensively planned hence more predictive and determinist evolution of the operational environment.

(4) The traffic, planned in such a way that its complexity reduced, follows it’s planned nominal 4D path and deviations from the 4D plan are exceptional. To obtain this result the system is devised so as to assure adherence to the 4D plan. The global architecture managing the plans and their executions is structured in such a way that it can at all times “reconcile” actual events with the plans hence operate in closed loop. This is enabled by a set of R&D product among which NOP, CDM, 4D, ASAS, …

(5) In this context, ERASMUS appears as a candidate to represent the concept of transition for the En-Route component to pave the way towards the SESAR and NGATS objectives. ERASMUS proposes a first step of automation with a nominal planning 20 mn ahead in order to reduce the complexity based on an autonomous system using 4D trajectory and Data-Link capabilities while respecting the human controller activity. Progressively the information quality and the predictability will increase, the time ahead will be extended from 20 mn to +60 mn ahead that will allow a better planning in order to assure a nominal traffic expedition with a minimum of deviation and a lower number of tactical intervention.

(6) The ATM system has relied primarily on the human brain, and therefore, the ability of the system to absorb and manage additional traffic is limited largely by the controller's ability to mobilize finite mental resources.

(7) Given the current state of knowledge and technology, an entirely automated system would be faced with insurmountable difficulties (e.g., preliminary certification of extremely complex software; fleet-wide upgrades and retrofit; numerous operational risks, etc.).

(8) ERASMUS proposes a compromise: a partially automated system that functions in tandem with the human operators. In the short term, this approach is essential to improving the current ATM system's capacity and effectiveness. In the long term, it can also support the goals of the SESAR project by providing a progressive transition towards a more fully automated system.

(9) In order for this approach to succeed, it must address the question of how best to incorporate automation to aid the controller in performing their current tasks, rather than changing those tasks to fit the needs of the automation. ERASMUS promises to make the controller feel more confident and comfortable with system safety even while increasing system capacity. It will do this by reducing the complexity of the sector traffic, and most importantly, without disrupting the operator's normal cognitive processes.

(10) ERASMUS presumes that the principal drain on the tactical controller's resources has more to do with managing uncertainty than with managing conflicts. Consequently, in order to reduce complexity ERASMUS must reduce uncertainty; it must minimize the number of traffic situations that the controller will perceive as having an uncertain conflict potential. With the integration of flights on a sector, traffic can be separated into two groups: those that do not present a conflict (i.e., separation > 15 NM), and those that may present a conflict (i.e., separation < 15 NM). ERASMUS' main role will be to reduce the number of planes that present an uncertain conflict potential by transforming them into planes without conflict (separation >15 NM).

(11) When extrapolating the present position and speed of each individual aircraft, the controller assumes large manoeuvring margins due to the limited accuracy of the available information. These margins create a "space" within which the ERASMUS system can optimise the traffic flow. Just as the airborne autopilot system performs minor adjustments (e.g., roll axis, level control) that are not perceivable by the pilot, the proposed ATC automation system would use slight adjustments (e.g., changes to vertical/horizontal speed, rate of climb/descent) to resolve potential traffic conflicts between different flights before they become apparent to the controller.

(12) To manage separations between planes (i.e, maintain a separation of > 15 NM), ERASMUS will automatically issue clearances that direct minor adjustments to the horizontal or vertical speed of the planes (- 3%, +6%). Theses adjustments will be so small that they will not be perceptible by controllers and therefore, will not to disturb their cognitive activity. Such actions can be described as `subliminal' because they are not consciously perceived by the controllers. These actions do not require the controller's attention; they do not interfere in any way with the controller's activities, their decisions, or their responsibilities.

(13) This subliminal control must be initiated in the upstream sectors (15 min ahead) in order to allow sufficient time to adjust separations before the integration of the flight into the sector (e.g., a +6% speed change applied to pair of aircraft over a span of 15 minutes will increase their separation by 6 NM +/-1 NM). These operations will be performed using 4D trajectory management and speed or RTA clearances that could be sent by any elementary data-link.

(14) This innovative type of control would be made more and more efficient as more and more aircraft are equipped with an automated "closed loop" control system - namely a FMS - that can increase and guarantee the accuracy of the 15 minute trajectory forecast. Encouraged by the benefits enjoyed by "early adopters", more and more operators will move to equip their fleet. Models predict that ERASMUS will significantly reduce the number of conflicts that require controller by as much as 80%. This could generate a 20-50% increase in sector capacity.

(15) The ERASMUS project proposes two other innovative applications: the Enhanced MTCD, and the ATC autopilot. These concepts will be addressed in future phases of the ERASMUS project.

(16) The ERASMUS applications are focusing on the en-route sector productivity.

1. Introduction

(17) This ERASMUS CONCEPT OF OPERATIONS is a document for both ERASMUS Management and all other project stakeholders. It provides information about the ERASMUS Concept of Operations.

(18) The concept description will provide the basis needed for research and development. Additionally, the concept will provide the operational context for the development of different applications for realisation in the Overall SESAR Architecture. It is, thus, an input document for SESAR.

(19) The "Concept of Operations" covers the en-route phase. It will:

- Describe the concept,
- Identify the main ATM actors,
- Describe the changes within the ATM components,
- Explain the different applications that will be tested,
- Outline the expected high-level system capabilities, and
- Outline "Impact Statements" which will highlight the effect of the changes on:
    - Human Aspects;
    - Procedures;
    - Systems.

(20) This document represents the ERASMUS project delivery D 2.2.1 part of the WP2.2 as defined in [2].

1.1. ERASMUS concept

(21) Considering the high level of automation and computing power that has been introduced into airborne systems during the last 50 years, with the Flight Management System (FMS) being a recent example, one wonders why similar levels of automation have not been implemented into the systems used by controllers on the ground. ERASMUS[1] proposes innovative solutions that promise to make better use of currently available technologies for the benefit of both the air and ground segments in a way that will support high levels of cooperation between human operators and automated systems.

(22) The strategic objectives addressed by ERASMUS are to propose an innovative ATM solution that is able to respond to the challenge posed by the projected increase in air traffic, and to improve the efficiency and safety level of the European Air Transport System as stated in the ACARE SRA II.

(23) ERASMUS advocates a cooperative approach aimed at defining and validating an innovative, human centred ATC technology that will improve the levels of sector safety and productivity while keeping controllers and the pilots in the loop.

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[1] The ERASMUS research project proposes to explore the potential benefits and the technological requirements of a concept that is derived from the personal work of Jacques Villiers [2003-2006], General Engineer of the French Civil Aviation (in retirement). This concept is the object of a French patent filing (N° 0313260 date :12 November 2003) and is also the subject of an opening of procedure of deposit in Europe and America

(24) ERASMUS will investigate the potential to manage complexity in high-density en-route airspace (Flight Level > 195) for the 2020 horizon.

1.2. Document structure

(25) This document is divided into 12 chapters:

- Chapter 1 gives a general description the Concept of Operation document;
- Chapter 2 is about the document information
- Chapter 3 gives a general description of the European ATM system 2020 constraints;
- Chapter 4 gives a description of the problems;
- Chapter 5 gives a description of the proposed solutions;
- Chapter 6 gives a description of the ERASMUS Services;
- Chapter 7 gives a general description of the ERASMUS applications;
- Chapter 8 gives a description of the integration of the ERASMUS elements into SESAR;
- Chapter 9 gives a description of the targeted ATM performance requirements;
- Chapter 10 gives a detailed description of the subliminal mode of operations;
- Chapter 11 gives a detailed description of the MTSA mode of operations;
- Chapter 12 gives a detailed description of the ATC autopilot mode of operations.

(26) This document includes also 3 annexes:

- ANNEX 1 gives a detailed description of the human factors issues;
- ANNEX 2 gives a general description of the operational environment;
- ANNEX 3 gives a general description off the enablers.

1.3. Document evolution & approval

(27) Revisions to the concept of operations will be done through periodic reviews performed in close cooperation with project partners. A group in charge of updating the operational content has been created and has also been tasked with collecting and integrating input from the different working groups and Work Projects.

(28) Iterative revisions to the operational concept will be performed on the following topics:

- Safety assessment and mitigation: a specific assessment of ERASMUS' impact on safety.
- Human factors: Once the ERASMUS concept is mature and stable, further analysis and studies will be performed to understand how controllers interact with the concept. This will be done by using prototypes, evaluation and simulations.
- Procedural aspect: a set of recommendations and instructions will be developed for controllers as well as for pilots. These may be associated with automated tools or rely on information sources.
- Technical aspect/Operational systems: specific technical devices for ground and onboard support have to be developed and integrated into the project.

(29) The graph below represents this iterative process:

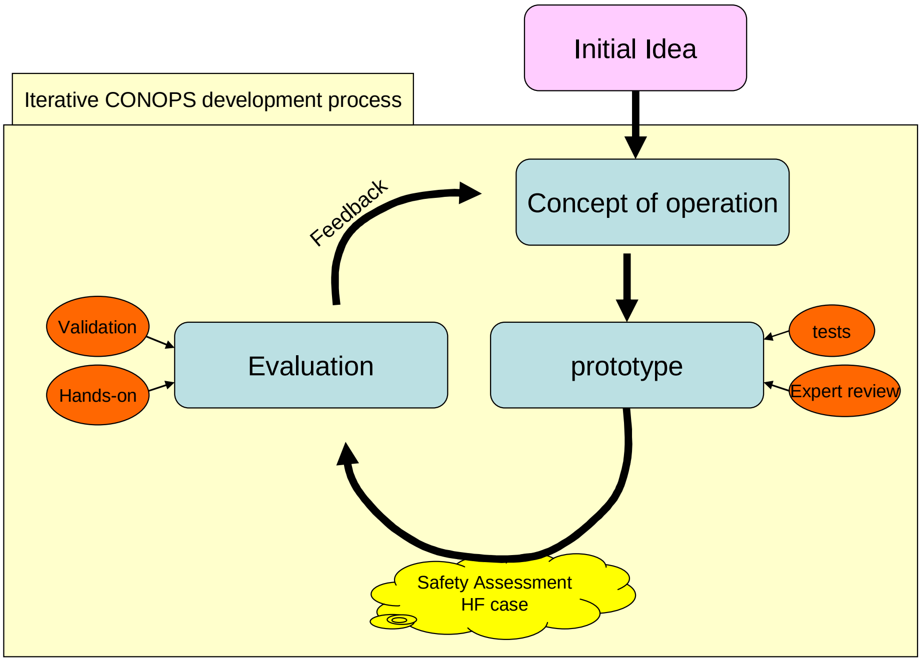

Figure 1: Operational concept iterative improvement process.

1.4. Reference material

(30) The documents referenced in this document includes:

[1] The EC ERASMUS contract TREN/06/FP6AE/S07.58518/518276;

[2] The ERASMUS Description Of Work (Released version – ERASMUS annex 1 – DOW – V1.0 ed 10 03 2006.doc);

[3] The ERASMUS Consortium Agreement (Released version - ERASMUS - consortium agreement 1.2.doc);

[4] ERASMUS Project Management Plan

[5] SESAR Definition Phase, Deliverable 1 (2006), *Air Transport Framework, The Current Situation*, DLM-0602-001-03-00, SESAR Consortium, Toulouse.

[6] SESAR Definition Phase, Task 2.1.2/D2 (2006), *Inventory of Existing Achievements and Ongoing Initiatives*, DLT-0607-212-ExecSum-00-04, SESAR Consortium, Toulouse.

[7] SESAR Airspace Users (2006), *Airspace User Operations, Vision Statements Document ATM 2020+,* AUO-VSD 1.0 (Mil Part 0.1), Version 1, Draft, SESAR Airspace Users Basic Consortium, Toulouse.

[8] SESAR Definition Phase, Task 2.2.2/D3 (November 2006), *SESAR Concept of Operations*, DLT0612-222-00-08, (Working draft), SESAR Consortium, Toulouse.

[9] SESAR Definition Phase (2006), Task 2.1.2 deliverable for SESAR D2 (17 November 2006), *Strategic Objectives Definition*, DLT-0607-212-01-02, SESAR Consortium, Toulouse.

[10] ERAMUS web site, www.atm-eramus.com

[11] SESAR DEFINITION PHASE (2006), TASK 2.1.2 DELIVERABLE FOR SESAR D2 (17 NOVEMBER 2006), *STRATEGIC OBJECTIVES DEFINITION*, DLT-0607-212-01-02, SESAR CONSORTIUM,

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[13] ICAO PANS-ATM Doc 4444, Fourteenth Edition, 2001.

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[15] C-ATM High-Level Operational Concept, Version 1.44, 24 January 2006.

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[19] Cognitive Aspects and Automation(1999), Leroux Marcel, 1st USA/Europe Air Traffic Management R&D Seminar, Orsay (France).

[20] Utilisation de la theorie de la detection du signal pour l'etude de decisions operatives : effet de l'experience des operateurs (1979), Bisseret A., Rapport I.R.I.A./C.E.N.A. C.0.7911-R60.

[21] Conflict perception by ATCS admits doubt but not inconsistency (2005), Averty P., in Proceedings of the 6th Air Traffic Management Research & Development Seminar, Baltimore (USA).

[22] Perception of Risks of Conflict by Air Traffic Controllers: the CREED Project (2006), Averty P., Guittet K., Lezaud P., Revue technique de la DTI, n°3, Juillet 2006, pp.33-66.

[23] Complexite et conscience de la situation, aides au controle de processus dynamique, d. Javaux, v De Keyser, iin Amalberti (ed.), Briefings, IFSA - Dedales, Paris

[24] Cognitive complexity in air traffic control: a literature review, B. Hilburn, EUROCONTROL, Note 04/04

[25] The effect of shared information on Pilot/controller and Controller/controller Interactions, R. Hansman and Hayley J. Davison, 3rd R&D ATM Seminar, Napoly, June 2000.

[26] Ironies of Automation, L. Bainbridge, AUTOMATICA 19 (6), pp 775-779, 1988

[27] LOOK : Safety Assessment for validating new concepts in Air Traffic Control, JY Grau, S. Guibert G. Gawinowski, F. Drogoul, L. Guichard, Proceedings in Aviation Psychology, Colombus, 2003

[28] The Performance Review Report, PRC, Eurocontrol, Number 8, 2004

1.5. Definition, abbreviations and acronyms

4D Business Trajectory	A 4D trajectory which express the business intention of the user with or without constraints. It includes both ground and airborne segments of the aircraft operation and is built from, and updated with, the most timely data available (AOC, FMS, …)
ACC	Area Control Centre
ADS-B	Automatic Dependant Surveillance – Broadcast
ANSP	Air Navigation Service Provider

AOC	Airline Operator Company
AOP	National Airspace System Operation
ATC	Air Traffic Control
ATCO	Air Traffic Controllers
ATFCM	Air Traffic Flow and Capacity Management
ATFM	Air Traffic Flow Management
ATM	Ait Traffic Management
ATS	Air Traffic Services
ASAS	Airborne Separation Assurance System
C-ATM	Collaborative Air Traffic Management (European Commission project)
CD	Conflict Detection
CDTI	Cockpit Display of Traffic Information
CFMU	Central Flow Management Unit
CONOPS	Concept of Operations
COTRAC	Common Trajectory Coordination
CPDLC	Controller-Pilot Data Link Communication
CR	Conflict Resolution
CREED	Conflict Risk Evaluation based on Expert Detection
CTO	Control Time Over
CWP	Control Working Position
DCL	Departure Clearance Service
DCS	Dowstream Clerance Service
ECAC	European Civil Aviation Conference
EC	Executive Controller
ERATO	En Route Air Traffic Organiser
ETA	Estimated Times of Arrival
ETO	Estimated Times Over Point
FLIPCY	Flight Plan Consistency Service
FMS	Flight Management System
HCA	Human Computer Automation
HF	Human Factors
HMI	Human Machine Interface
JCS	Joint Cognitive System
KPA	Key Performance Area
NM	Nautical Miles
MSP	Multi-Sector Planner
MTCD	Medium Term Conflict Detection
MTSA	Medium Term Separation Assurance
NTCD	Near Term Conflict Detection
NOP	Network Operational Plan
PC	Planner Controller
RTA	Required Time of Arrival
SESAR	Single European Sky Applied Research
STCA	Short-Term Conflict Detection
SWIM	System Wide Information Management
TC	Tactical Controller
TCM	Traffic Complexity Management
TP	Trajectory Prediction
TPS	Trajectory Prediction System (Ground)
TTA	Target Time of Arrival

Table 1: Acronyms and abbreviations

Activity	Real aspects of the human work (= the effective task)
Autonomy	• System or agent autonomy with respect to its self-capability to accomplish its assigned mission goals without any or with minimal external cooperative intervention while operating under constraints and dynamic environment. • Autonomy reflects the system or agent decision-making capability and authority (responsibility), and the degree of self-control the system or agent has over its own decision
Attention process	Process by which controllers selectively concentrate on one thing while ignoring other things.
Automation Ironies	The paradoxical or unexpected impact of automation on the human operator (e.g., increase in workload).
Co-action	Situation where, at least, two agents (automation or human) cooperatively act on the same object, in the same temporal window, in a same geographic area.
Cognitive economy	Distribution (accomplished by various mechanisms and strategies) by which humans allocate internal resources in the performance of tasks and/or activities.
Cognitive process	Human mental mechanism which is used during the performance of a task and/or activity.
Commitment feeling	Subjective commitment of the responsibility in the activity (to be distinguished from the prescribed responsibility)
Complexity	Complex systems are characterised by: • <u>Dynamism</u> - the specifics of the situation change spontaneously (without direct operator input). • <u>Continuous momentum</u> - it is not possible to stop the process to alleviate time-pressures. • <u>Interrelatedness</u> - Complex linkages and interactions exist between system elements. The entire system may become disabled or completely cease to function if one or more elements are removed. The couplings between elements may be tight or loose, depending on the type of system, and therefore exert less or more influence on the system. • <u>Unpredictability</u> – The consequences of acting upon the system are difficult to anticipate because elements may interact in unforeseen ways. This poses a high risk when the consequences of the actions are safety-critical. • <u>Opacity</u> - the internal system behaviour is neither explicit nor directly accessible.
Difficulty feeling	Human subjective assessment and actual experience of the difficulty which is related to a given situation
Doubt management	Process which is linked to the cognitive economy strategy and which seeks to balance the level of mental resources required to reduce the level of doubt with the level of perceived workload.
Perceived risk	Subjective assessment of the potential risk of conflict for a given traffic pattern, which is based on the air traffic controllers' perceptual processes.
Perceptive process	Processes by which controllers interpret and organize the information they perceive into a meaningful understanding of the traffic situation.
Safety feeling	Human subjective assessment of the danger posed by a given traffic situation.
Separation	Minimum separation distance between aircraft - Values are defined by ICAO
Spacing	Techniques to maintain specific spacing between aircraft
Subliminal	Below the threshold of conscious perception.

Task	Prescribed aspects of the human work.
Perceived Effort	Human subjective assessment, based upon their actual experience, of the level of mental resources that must be called upon in the performance of a task.

Table 2: Terms definitions

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2. EUROPEAN ATM SYSTEM - 2020 CONSTRAINTS

(31) Air traffic is expected to triple by 2025. However, the current air traffic management system is very close to its functional capacity and does not yet take advantage of modern automation that could accommodate the expected traffic increase. This will inevitably lead to airport and en-route congestion and a significant increase in traffic restrictions.

(32) The main focus of the ground based European operational concept is set at sector level with different methods of operation across Europe. The Performance Review Report number 8 [28] suggests that "raising controller productivity and support costs to 3rd best achieved levels in Europe would improve cost-effectiveness by 56% and 23% respectively. Every 10% improvement in cost-effectiveness is worth some € 700M per annum".

(33) The lack of predictability and warning of events exacerbates problems related to the flow of traffic en-route and in terminal airspace; furthermore, airspace users and ATM service providers optimise their operations independently which leads to inefficiency. This lack of predictability means that Central Flow regulation and slot action taken to protect sectors from overload can actually lead to inefficiency and result in a significant loss of slots.

(34) PRR8 identified flight-efficiency "as a major contributor to ATM performance: en-route horizontal inefficiencies alone are estimated at €1,000M - €1,500M per annum". Furthermore, it suggests that "improved predictability of air transport would generate high added-value: compressing half of flight schedules by 5 minutes on average would be worth some €1,000M per annum in better use of airline and airport resources".

(35) Lack of integrated processes and procedures together with long implementation lead times typical of new infrastructure has meant significant pressure on gates, taxiways and runways at peak times with an associated impact on airspace user operations.

(36) Currently, capacity constrained airports use stacks and extended approach patterns to maintain pressure on runways. Tactical traffic management that smoothes in-bound flows need to be developed in order to improve the airport capacity-delay trade-off by minimising such delays while maintaining runway throughput.

(37) Considering the above, the SESAR operational concept proposes to concentrate on the following limitations:

- Capacity, sector productivity, and support costs;
- Information distribution and fragmented and uncoordinated decision making processes;
- Lack of European ATM integration, disparate processes and non-uniform services;
- Airport arrival, departure, taxiway and aircraft turnaround processes;
- Adverse weather affecting surface and airspace operations;
- Poor use of existing technology and operational capability.

(38) The challenges that need to be dealt with when addressing these constraints include the need to increase safety, to be cost efficient and to take into account increasing environmental concerns.

(39) It must be recognised that the social issues concerning trends towards automation and changes in the ATM working environment should be resolved in parallel with system evolution to ensure safe and correct functioning. Furthermore, it is important that security issues are addressed to ensure a "secure" ATM system.

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3. PROBLEM IDENTIFICATION

(40) As stated by SESAR [5] : "The current ATM System has humans at the centre of virtually all activities and this has been at the heart of providing safe, high quality air navigation services. However, expectations are that in some cases the human will not be able to deal with the future level of traffic and its complexity in the same way as is done today. There is a need for a paradigm shift in the current concept of operations to break through the "capacity barrier" predicted to occur between 2013 and 2015 and to meet the future business challenges. This shift will include an increased use of automation to do some tasks traditionally performed by humans."

(41) The management of the overall system complexity requires deeper and more exhaustive demands on limited human resources [23]. Thus complexity is considered to be the main constraint on controller productivity [24].

(42) Therefore, ERASMUS has decided to focus on the management of complexity[2] in the future ATM environment.

(43) The basic assumption underlying the ERASMUS project is that a part of complexity management should be transferred to automation in order to improve operational performances.

(44) The objective of the ERASMUS project is therefore twofold:

- To find an appropriate level of automation in order to reduce the ATM system complexity and increase efficiency.
- To take into account the human and machine limitations and exploit their respective capabilities in the best possible way.

(45) Consequently, the ERASMUS project identifies and deals with two main problems:

- Problem area 1: To define the impact of the overall ATM system complexity on the controller. The question derived from the complexity problem is expressed as follows:

  Question 1.1 How to reduce the complexity and ease the controller burden?

  To achieve this objective, ERASMUS aims at an optimal interaction between the human actors and the machine [25] [26] while ensuring that the impact on pilots is acceptable and that pilot interaction with enabling technology is operationally viable.

- Problem area 2: The Human – Machine interaction[3]. The questions derived from the Human-Machine interaction problem are expressed as follows:

  Question 2.1 How to ensure an optimum balance (in terms of task allocation) between the human and the machine?

  Question 2.2 How to share the responsibility between the agents (controller, pilot and machine)?

  Question 2.3: How does the use of onboard technical systems dedicated to

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[2] ERASMUS is dealing with one component of the complexity related to the traffic. There are others elements of the complexity [24] not taken into account here (e.g. airspace design, traffic route assignment, …)

[3] The term "interaction" is used here in the widest sense of action or influence of people or things on each other. It includes the controllers, pilots and machines as a global socio-technical system.

ERASMUS impact pilot operation and performance?

(46) The operational solutions proposed by the ERASMUS project are designed to answer these questions. They are presented in the next chapter (see chapter 6).

4. OPERATIONAL SOLUTIONS

4.1. Introduction

(47) The ERASMUS operational solution addresses the problems identified above by exploring the following strategies:

- Acting on the traffic complexity delivered to the controller.
- Acting on the level of information exchanged between the human and the machine and on the level of autonomy / dependency of the agents.

(48) The following chapters will address the rationale behind each strategy, how these strategies might be carried out (i.e., the principles) and the related working hypotheses.

(49) The detailed human factors theoretical constructs that support the operational solutions will be developed in ANNEX-1 (Human Factors: Theoretical model).

4.2. Solution to the complexity problem

(50) The essence of the controller's work lies in deciding when and how to act in order to manage traffic [21]. According to the available data, it appears that controllers make their decisions based on the actual position of aircraft and traffic prediction, or on extrapolated aircraft positions.

(51) Conflict and density parameters alone are not sufficient to understand and represent the complexity [24]. For instance, from a controller’s point of view, the uncertainty of whether or not the observed traffic represents a developing conflict is one of the most important elements in the system's perceived complexity.

(52) Controllers mitigate uncertainty using a cognitive reasoning mode called doubt [19]. Doubt reasoning allows the controller to plan actions and contingencies based upon the control of a given environmental parameter. It provides the controller with a way to choose a strategy that is appropriate to the uncertain nature of the data.

(53) The controller categorises the traffic into “doubt” and “no doubt” situations according to the results of their doubt management process. Managing doubt is considered one of the principal drains on the tactical controller's finite cognitive resources [20].

(54) In order to reduce complexity ERASMUS must reduce uncertainty; it must minimize the number of traffic situations that the controller will perceive as having an uncertain conflict potential. With the integration of flights on a sector, traffic can be separated into two groups: those that do not present a conflict (i.e., separation > 15 NM), and those that may present a conflict (i.e., separation < 15 NM). ERASMUS’ main role will be to reduce the number of planes that present an uncertain conflict potential by transforming them into planes without conflict (separation >15 NM). In ERASMUS, the categorisation of aircraft as "with conflict" and "without conflict" is based only on an extrapolated minimum distance between aircraft.

(55) The ERASMUS project has chosen to reduce controller uncertainty using the following strategies:

- Change the traffic distribution (transfer of aircraft from “doubt” into “no doubt” situations);

- Improve the traffic prediction information (information provision to the controller).

(56) However, ERASMUS will ensure that any positive aspects of doubt are preserved (e.g., importance of revision reasoning, expertise building) [19][22][27].

(57) The principle proposed by ERASMUS involves reducing the controller's uncertainty by managing the traffic distribution.

(58) This principle is based upon the following hypotheses:

- Situations of "doubt" and "no doubt" exist for the controller.
- Reducing controller uncertainty will conserve mental resources.

4.3. Solution to the Human – Machine interaction problem

4.3.1. Levels of information and autonomy

(59) The goal of manipulating the level of information exchanged between the human operator and the machine, as well as the level of autonomy / dependency of both of these agents, is to limit interference and minimize disruptions to the human cognitive processes [25].

(60) The span of information exchanged between a "machine" system and the human operator can range from "all" to "none". Likewise, the "machine" system can range in functionality from completely independent of the human operator to completely dependant. However, the level of information exchange and the level of autonomy can vary independently of one another.

(61) ERASMUS assumes that every single piece of information provided to the controller will have an impact on his or her cognitive processes and subsequent task performance. Parameter changes or additional provisional information will be "noticed" and processed in one way or another by the controller. Full autonomy can only be achieved when no information is exchanged between the human and the machine. This leads to the following assumption:

A fully autonomous system is subliminal - it operates without the conscious recognition of the operator.

(62) To manage separations between planes (e.g., maintain a separation of > 15 Nm), ERASMUS will automatically issue clearances that direct minor adjustments to the horizontal or vertical speed of the planes (- 3%, +6%). Theses adjustments will be so small that they will not be perceptible by controllers and therefore, will not to disturb their cognitive activity. Such actions can be described as `subliminal' because they are not consciously perceived by the controllers. These actions do not require the controller's attention; they do not interfere in any way with the controller's activities, their decisions, or their responsibilities.

(63) The ERASMUS project also makes the following hypothesis regarding human-machine interaction:

The controller will not be disturbed by the minor aircraft speed variations computed by the technical system, as other minor speed variations are already present within the system (e.g. wind effects).

The controller is not disturbed by having to decide whether or not delegating a task to the technical system.

A dedicated HMI can provide information to reduce doubt without disturbing the controller's task performance or cognitive activities.

4.3.2. Impact on On-board Side

(64) ERASMUS requires specific onboard equipment and specific inputs and procedures for the pilots.

(65) The en-route phase of flight does not place a heavy task load upon the pilot - it is relatively free of activity. Therefore some additional tasks could be allocated to the pilot with minimal negative impact upon their cognitive activities and task performance. Moreover the reduction in traffic complexities promised by ERASMUS (i.e., fewer conflicts and increased time for decision-making) should also serve to mitigate pilot workload by reducing the number of clearances issued by ATC and deviations from the planned routing. Therefore, the ERASMUS project makes the following hypothesis:

ERASMUS integration into the flight deck will be acceptable and will not overload the pilot.

4.3.3. The responsibility issue

(66) The allocation of responsibility has been identified as a major issue that will need to be addressed. This allocation - and the related certification, legal and social issues - will determine acceptability of any new technical system. This remains an open topic of discussion and no solution has yet been identified. There are currently no documents available on this particular subject.

(67) However, the ERASMUS project assumes that any solution will require that the technical system be reliable and that it comply with any certification or legal constraints. Furthermore, it must clearly define the extent to which responsibility, and the related procedures, is shared between the agents. This must be based upon an analysis of the operational situation, and the decision making and task performance requirements

(68) Therefore, the ERASMUS project makes the following hypothesis:

The ERASMUS system needs to be certified to be accepted by the operators.

(69) The following chapter describes how the ERASMUS system complies with and supports the principles put forth by the SESAR project. It also introduces the three proposed ERASMUS applications that will be used to address the traffic complexity issues previously described (see Chapters 5 and 6).

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5. ERASMUS SERVICES

(70) To address the different operational solutions that have been identified, the following set of services are proposed :

- Traffic Complexity Management Service;
- Separation Assurance Service;
- ATC autopilot Service;

5.1. Traffic Complexity Management Service

(71) The Traffic Complexity Management service aims at reducing the complexity of a sector (or a cluster of sectors) by automatically adjusting the provision of separation between the inbound flights. This service provides part of the dynamic ATFCM with a combination of “flow and capacity management “and of “Multi-Sector Planning” (MSP).

(72) The objective of Traffic Complexity Management is to ease the controller's workload and free-up some of the controller's mental resources. It will achieve this by minimising the number of traffic situations that the controller feels must be monitored due to the perceived level of conflict risk.

(73) In order to accomplish this, traffic must be managed in a way that produces separations that controllers perceive as posing little, if any, risk of conflict. The ERASMUS system will achieve these separations using adjustments to aircraft speed (i.e., limited horizontal and/or vertical changes) within a speed envelope and constrained to a medium-term time horizon.

(74) By keeping the commanded speed change to a low percentage of total aircraft speed (e.g less than 6%) and accurately predicting when these types of changes are necessary, ERASMUS will manage traffic complexity "behind the scenes". This approach will minimize controller workload while still allowing them to perceive and evaluate the traffic independently of the system.

5.1.1. Principles

(75) However, it is important to understand the current partition of traffic in order to understand how ERAMUS can intervene. The figure below presents a typical traffic distribution:

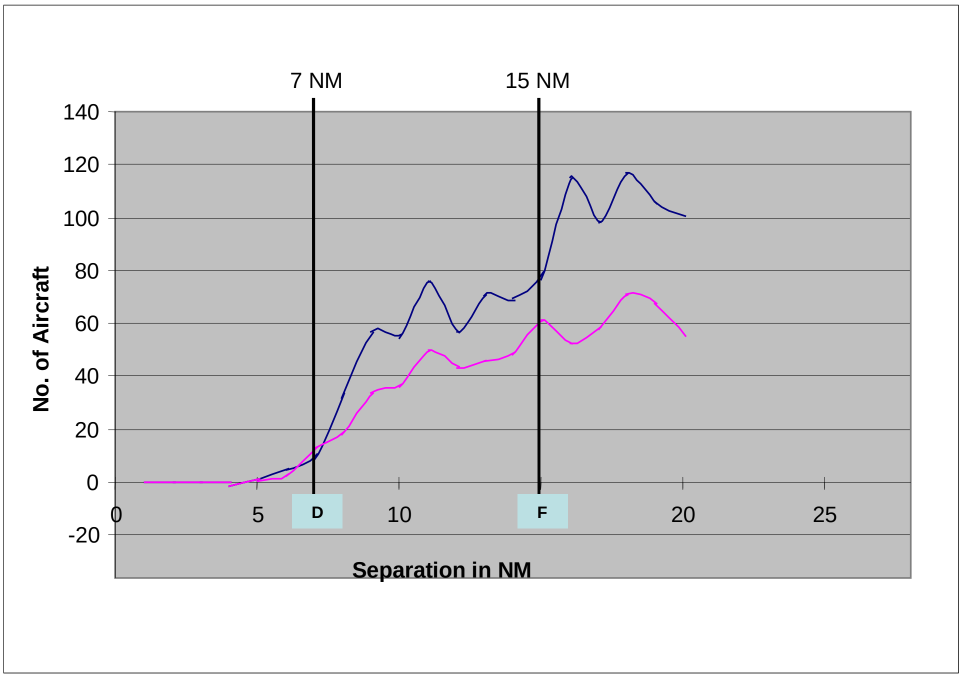

Figure 1: Aircraft separation distribution (Aix ACC traffic sample)

(76) From expert judgements, looking at the aircraft separation distribution (Aix ACC traffic sample), it should be considered a first threshold called D (dangerousness) of value 7 NM under which one does not want to see planes separation and a threshold F of value 15 NM to the top of which the controller does not perceive the need to interact with the traffic. It is interesting to note that these values are far away from the 5 NM separation ICAO standards and represent the room of manoeuvre taken by the controllers to manage the uncertainty.

(77) These values (7 NM and 15 NM) must be taken into account with precaution [22] because they represent order of magnitude and depends of the sector configuration, traffic context, … and will be refined and validated during the project.

Separation	Action of the controller
Above 15 NM	No doubt for the controller. Conflict-free situation.
From 7 NM to 15 NM	The controller has **doubts** and monitors the situation.
Below 7 NM	No doubt for the controller. Interventions are taken (i.e. heading, speed regulation).

Table 4: Rough separations used for flight integration[4]

(78) For traffic in the interval defined by [D – F], the controller is uncertain whether the plane will ultimately move into the partition [0 - D] or into [>F]. Therefore, the controller feels that these aircraft require monitoring.

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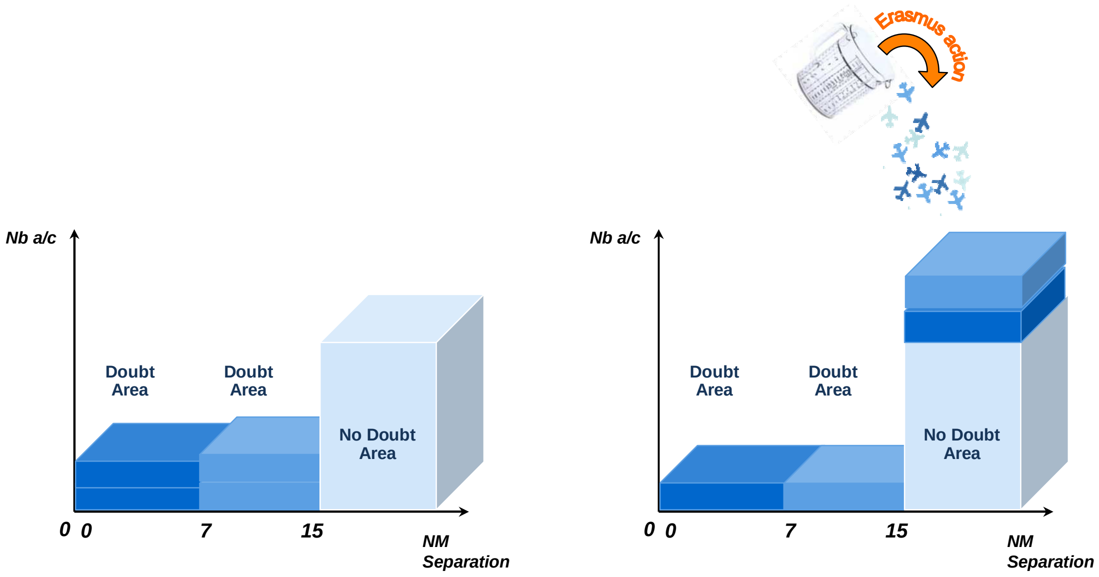
[4] The values of this table shall be validated during the experimental process.

(79) The objective of the ERASMUS filter is to provide the controller with a traffic partition which minimizes the occurrences of doubtful traffic (i.e., those in partition [D – F]).

(80) The ERASMUS filter must deliver a distribution of traffic with fewer planes in the partition [D – F] and a more planes in the partition [>F]. (See Fig. 3).



Traffic distribution before ERASMUS actions

Traffic distribution after ERASMUS actions

Fig 3 – Traffic partition shift

5.1.2. Function Implementation

(81) When aircraft enter into the sector with a 5 NM minimum separation, the controller still considers the situation as meriting attention. This is because controller's perceive the 5NM separation as insufficient to assure that the situation will remain conflict-free. Therefore, they will continue to monitor these aircraft. It is not until the traffic separation exceeds 15 NM that the controller feels that these aircraft pose no risk of conflict. It is this "fuzzy area" created by the controllers themselves that offers an unexpected but welcome opportunity: to reduce controller workload by fully exploiting computer capabilities without encroaching on the controllers domain, without infringing upon their independence, and without interfering with their responsibilities..

(82) ERASMUS will modify aircraft trajectory by issuing minor changes to the vertical and/or horizontal speeds. These speed changes will be so small that they will not be perceivable by the controllers, but will still be sufficient to move the aircraft involved from the "doubt" partition

(7–15 NM) to the “no-doubt” partition (> 15 NM). However, a closed-loop control must be established between ground and airborne computers via data-link.

(83) ERASMUS must create enough space between aircraft with regard to the controller’s perception criteria (i.e., target separation in Nm). The magnitude of speed changes issued by the system is limited by the manoeuvring room allowed for each aircraft (i.e., the speed envelope) and is also constrained by a medium-term time horizon.

(84) Several dependent constraints should be respected:

- The time horizon within which it is possible to accurately predict the future position of aircraft.
- Speed variation capabilities.
- Controller perception concerning speed variation and aircraft trajectory alteration.
- Operational constraints.

5.1.3. Traffic Partition

(85) The traffic is naturally divided in three partitions (see diagram below):

- traffic incoming with a separation less than D (*at this stage the value is fixed to 7*);
- traffic incoming with a separation between D and F (*at this stage the value is fixed to 15 NM*);
- traffic incoming with a separation greater than F.

(86) The figure below presents the expected traffic partition for the incoming traffic within a 15 minute time frame:

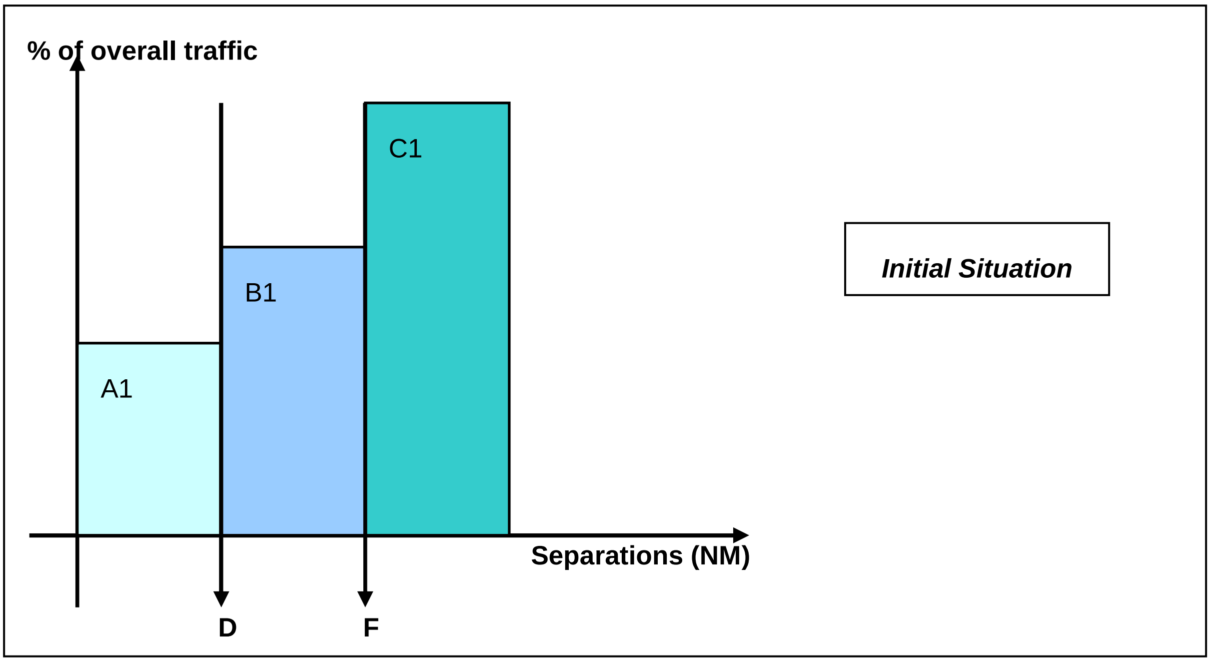


Fig 4 – Expected traffic partition (without ERASMUS)

(87) This figure shows the traffic partition shift from the B partition into the C partition expected when ERASMUS is in operation:

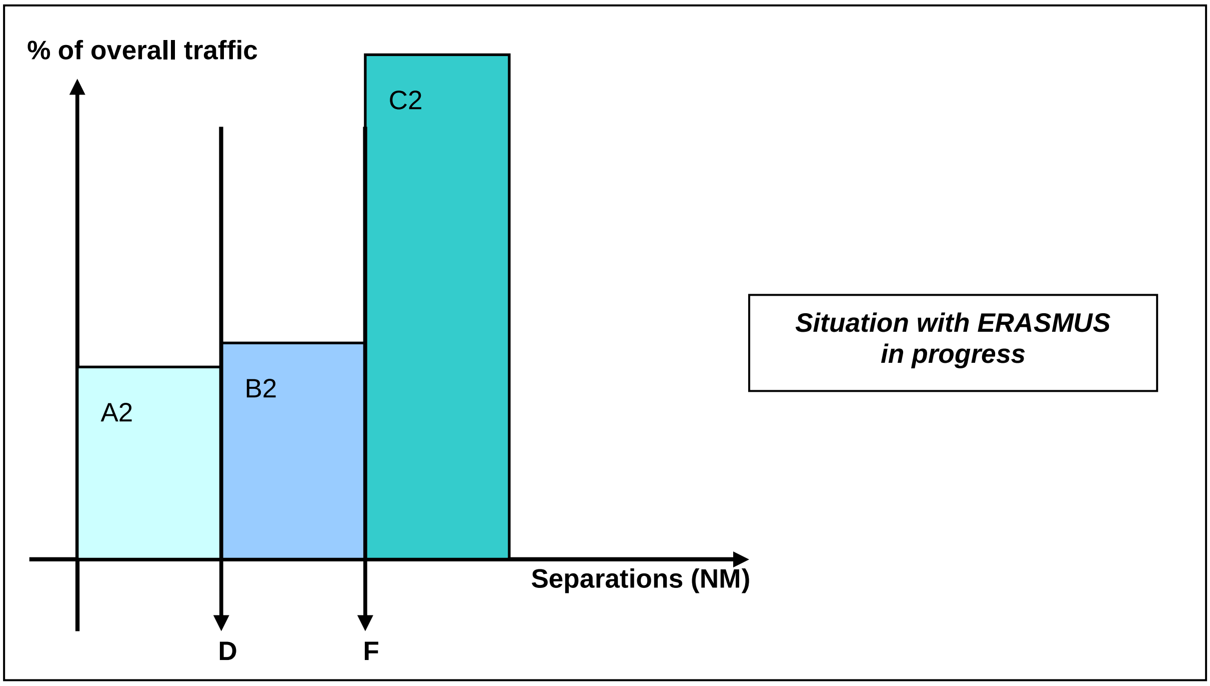


Fig 5 – Traffic partition shift with ERASMUS in progress

(88) After the Erasmus action modifies the traffic partition, the only certainty is: A1+B1+C1 = A2+B2+C2.

5.2. Separation Assurance Service

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5.3. ATC Autopilot Service

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6. ERASMUS APPLICATIONS

(89) In order to develop the different services, the ERASMUS concept proposes three different applications that range from no automation to a fully automated system. Figure 6 below provides another perspective and indicates the relative levels of automation for each application.

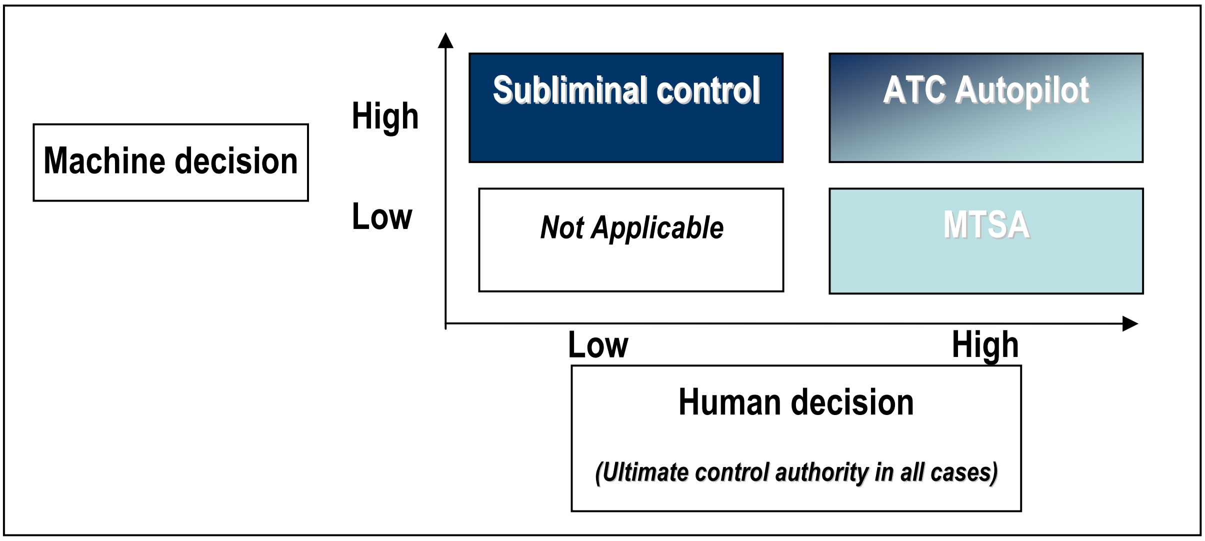

Fig 6 – ERASMUS Level of Automation

(90) An overview of the three applications - "Subliminal Control", "ATC Autopilot", and "MTSA" - will be detailed in chapters 9, 10 and 11 respectively.

6.1. The Subliminal Control Application

(91) The "Subliminal Control" application will employ the "Traffic Complexity Management" Service in order to reduce the complexity of a sector (or a cluster of sectors). It will automatically adjust the Provision of Separation between the inbound flights with minimal disruption to the tactical controller. The Subliminal Control application is defined as follows:

- "*Control*" means that a ground clearance is issued and followed by the cockpit crew.
- "*Subliminal*" refers to a clearance that is not issued by the controller in charge of the flight, nor is the controller made aware of the clearance. Furthermore, the effects of the control are below her/his threshold of perception.

(92) The management of complexity includes, but is not limited to, resolving conflicts. The ground system takes the ATCo's perspective into account as much as possible. It does not manage traffic conflicts as defined by ICAO, but follows an approach similar to that used by the controllers. This approach is called "Perceived-Risk" (see definition in table 2).

(93) Given that each instance of Perceived-Risk consumes a significant portion of the controller's cognitive resources, ERASMUS aims at reducing the uncertainty surrounding incoming traffic as much as possible. By directing aircraft in a manner that facilitates separations that fall outside of the controllers' "potential conflict" criteria, ERASMUS will ease the controller's task burden and increase sector efficiency.

(94) Once a flight is integrated within a CWP, the subliminal control action can be considered "complete" for the corresponding sector, but it can be engaged for adjacent sectors.

6.2. The Medium-Term Separation Assurance (MTSA) Control Application

(95) The Medium Term Separation Assurance (MTSA) application refers to a concept that was initially called “enhanced MTCD”. While MTCD only considers conflict detection, the MTSA tries to provide information to the controller about aircraft separation in order to help them identify situations that may pose a conflict risk.

(96) MTSA will provide information about the real-time traffic complexity. This information will assist the controller in assessing the traffic situation and decision-making. In addition, the MTSA will provide information about aircraft separations guaranteed by the ERASMUS technical system.

(97) Because this information will be timely, accurate, and will not disrupt the controller's cognitive process, the MTSA will reduce the total number of tactical interventions.

6.3. The ATC Autopilot Control Application

(98) Because of the information provided by the Medium-Term Separation Assurance (MTSA), the controller will be better able to elaborate a strategy and decide whether to delegate certain traffic situation to the machine for resolution. Once delegated, ERASMUS will ensure separation by through minor adjustments to speed or rate of climb in a closed-loop air/ground system.

(99) In comparison to the current ground system, an aircraft's en-route attitude and trajectory control can be delegated to the automatic pilot. The pilot can define flight parameters and then let the automation manage their control while retaining the authority to alter any flight parameter at any time. In other words, the pilot determines strategy while the FMS executes closed-loop tactical trajectory adjustments, some of which may not even be perceived by the pilot.

(100) However, it is important to note that ERASMUS will not infringe upon the authority - nor reduce the responsibility - of either the controller or the pilot. ERASMUS action will be limited to managing only the traffic delegated to the "ATC autopilot" function. Controllers will still be able to issue any classical clearances and the pilot will still be able to modify the flight plan after agreement with the controller.

(101) Any new responsibilities allocated to ERASMUS are the result of explicit delegation by the controller and each is acknowledged by the ERASMUS system. For example, a controller monitoring board could show the status of all sector traffic and indicate which aircraft are being handled by the controller and which have been delegated to ERASMUS for management.

(102) In the future, once the necessary data link and airborne software are available, the aircraft's onboard system could be given the responsibility for automatically assuring separation whenever possible, alerting the controller and the pilot as necessary.

7. ERASMUS ELEMENTS INTEGRATION INTO SESAR

(103) This chapter presents the high level operational principles of the ERASMUS project. These principles are applied to the three conceptual applications developed in the next chapters. Theses principles also comply with the vision of the Air Transport Framework proposed by SESAR (See [5], [7], [8]).

7.1. Introduction

7.1.1. A Layered Planning Architecture

(104) The ERASMUS and SESAR architectures are based on the layered planning approach to traffic management (Fig. 7). Layered planning is a continuous process of assessment, management, and re-assessment to achieve an optimal balance between capacity and demand. Layered planning is also collaborative with the phases of planning strongly influenced by the quality of available information, the time when that information is used, and the purpose to which it is relevant. The Network Operations Plan is developed during the layered planning phases.

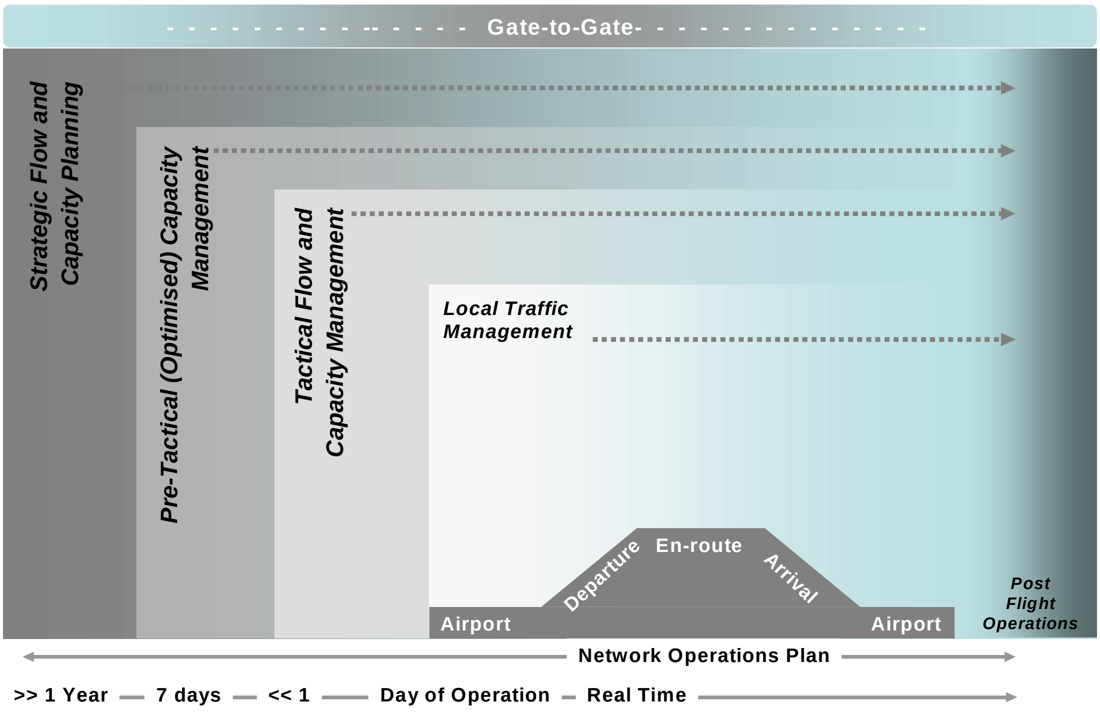

Figure 7 - Layered Planning

(105) The following planning layers are defined:

- **Strategic (*From >12 months to 1 week before operations*):** Demand and capacity determination, actions required to balance demand and capacity, long term military plans, airspace design and development of initial Network Operations Plan. Local alternative scenarios for dealing with unforeseen events are developed and coordinated with the network manager.

- **Pre-Tactical (*7 days before operations*):** Demand and capacity balancing based on users refined traffic plans (including the 4D profile from historic data or the airspace user, according to the look-ahead time) military airspace use, alignment of airport slot and stand allocation plans, and weather forecasts.
- **Tactical (*day of operation*):** Airspace configurations are promulgated and slot allocation (arrival and departure capacity balancing) 4D plan negotiation and pre-tactical clearances are negotiated. Re-balancing capacity and demand, traffic management and synchronisation occurs whilst planning risks are monitored and solved.

(106) Within this layered planning architecture, the current ATFCM approach relies on understanding the constraints on system capacity and on developing effective management strategies to minimize the impact of limited slot allocations on Aircraft operators. The ATFCM continuously monitors and evaluates all possible ATFCM solutions through an iterative and seamless process, from strategic planning to tactical execution of operations (see Fig. 8).

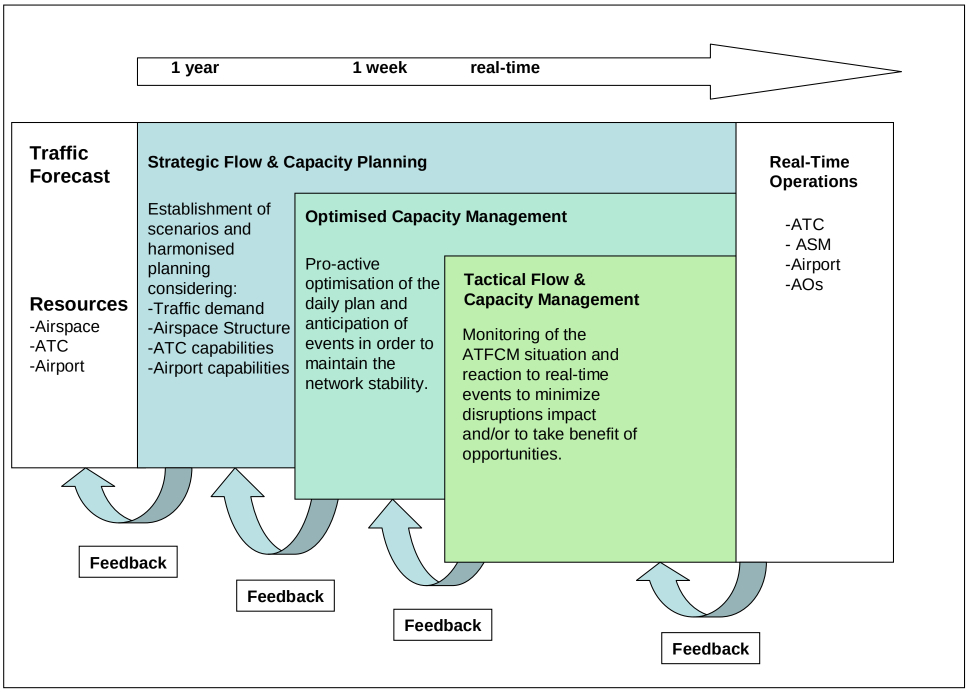

Fig 8 - ATFCM Seamless Process

(107) In the "Tactical Flow & Capacity Management" process, the ATFCM monitors the situation and reacts to real-time events. ERASMUS is seen as a next step in ATFCM as it manages traffic to create capacity efficiencies. ERASMUS will move the ATFCM from a concept based on "static traffic monitoring and reaction" towards a concept based on anticipation and dynamic interactions (see Fig. 9).

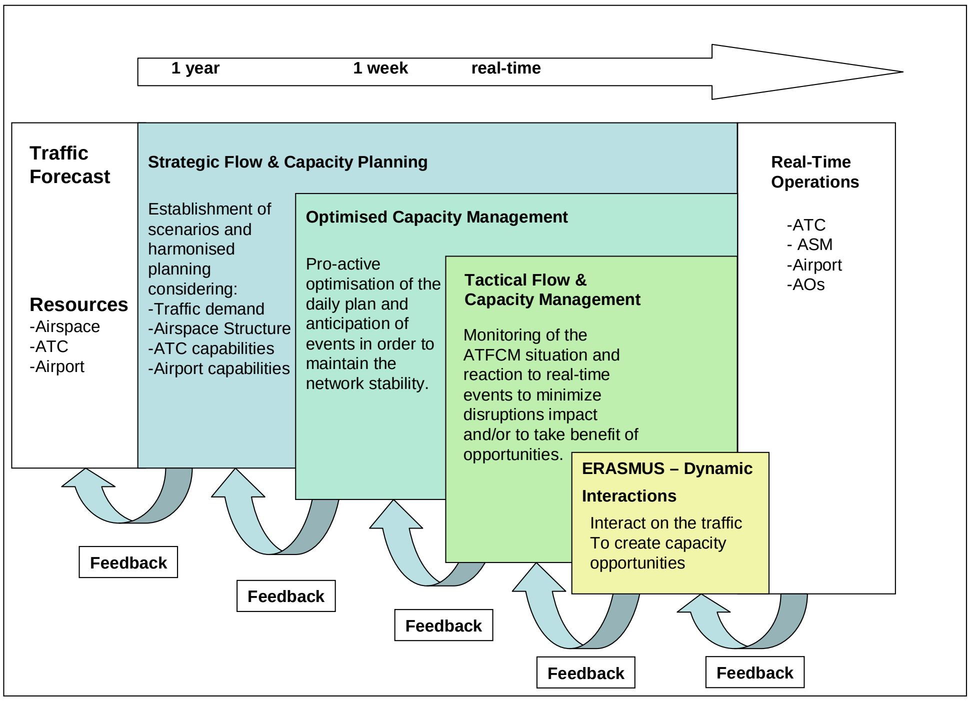

Fig 9 - ATFCM Seamless Process

7.1.2. New Services that will be delivered to the airspace users

(108) SESAR proposes a new vision of the services that will be delivered to airspace users ([8], [14]). This vision is complementary to the traditional frame of services defined by ICAO and is focused on two main pillars:

- The Trajectory Management;
- The Conflict Management.

(109) The core SESAR concept introduces and expands two main trends for further development:

- The increased involvement of airspace users in defining 4D trajectories that take into account their business needs (See Fig. 10);
- The move away from tactical to strategic management of flights according to three main phases of the ATM process: Business Development Phase, Planning Phase and Execution Phase.

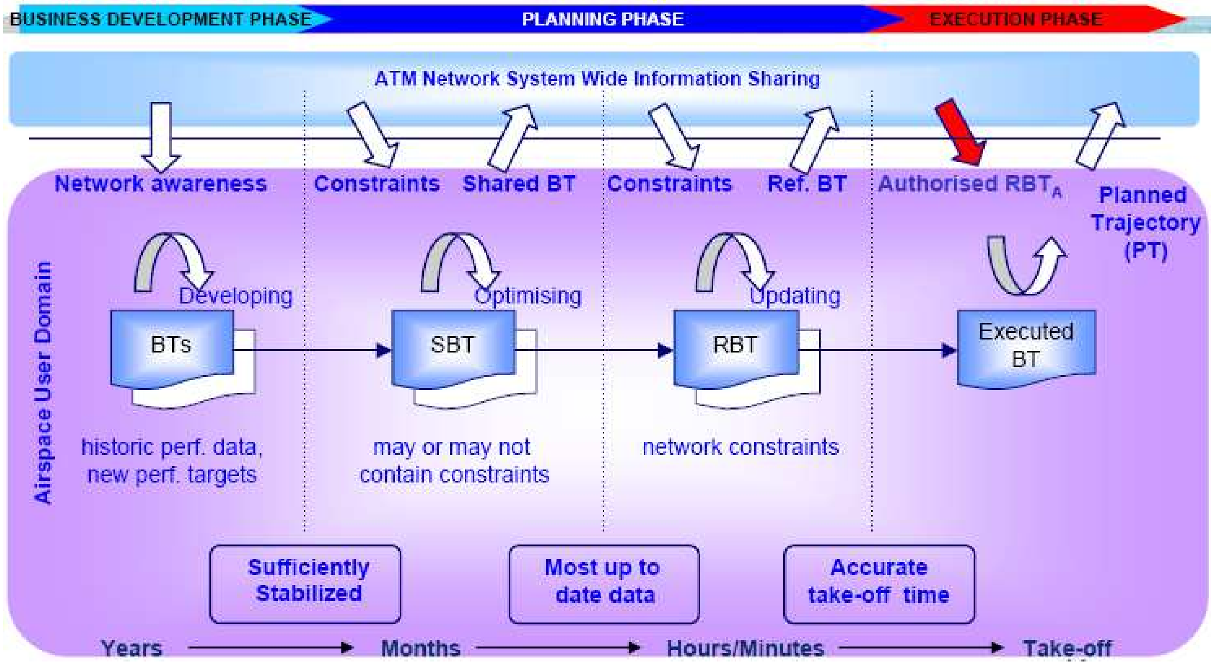

Figure 10 - Business Trajectory Lifecycle promoted by SESAR

(110) The ERASMUS project is fully in line with this collaborative refinement of 4D trajectories. Furthermore, the innovative applications proposed by ERASMUS will facilitate adjustments to the Executed Business Trajectories for En Route sectors (note: the scope of ERASMUS is limited to airspace over FL195).

(111) ERASMUS also promises new solutions for strategic ATM activities (i.e. to provide traffic distribution and separation according to specific rules) and for Tactical ATM activities (i.e. assist in the management of separations).

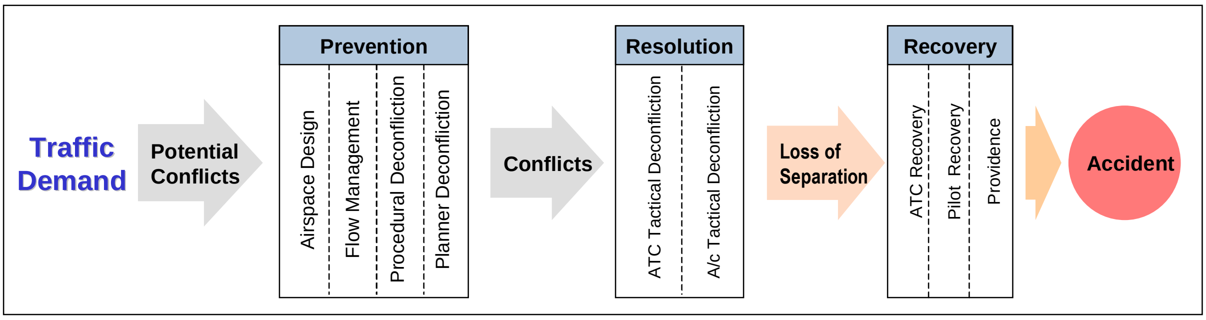

Figure 11 - Current ATM Barrier Model

(112) The current ATM Barrier Model (See Fig. 11) is still relevant and SESAR re-enforces this model by adding the new layers listed in Table 4.

ERASMUS action

Barriers	Prevention	Resolution	
New layers	***4D Trajectories shared by air and ground***	***Controller Tactical Separation Provision***	*Short Term Conflict Alert*
	Collaborative layered planning processes	***Time-based spacing and separation***	*Airborne Collision Avoidance System*
	Complexity Management	*ASAS applications*	*Minimum Sector Altitude Warning*
	User Assisted Delay Management	*Self-Separation*	*Ground Proximity Warning*

Table 4 - New layers in the ATM Barrier Model

(113) SESAR stated that controller workload is the main limitation to airspace capacity (See [8]). In order ease this burden, the ERASMUS concept will:

- Reduce the complexity of the traffic before its integration within the sector (i.e., the "prevention barrier").
- Provide tactical controllers with advanced functions that will customize the provisions of separation (i.e., the "resolution barrier").

(114) SESAR identified ASAS applications as a possible method to improve capacity. ASAS and ERASMUS are fully compatible and complementary. The main difference between these two concepts lies in the conflict management timeframe: ERASMUS actions can be engaged up to 30 minutes ahead the CPA while ASAS focuses on the management of aircraft that are already near the separation limits. ERASMUS functions cooperatively with ASAS, allowing the ASAS application to transfer spacing or separation responsibility to the aircraft. Furthermore, ERASMUS may also take advantage of the results of the on-going ASAS studies.

7.2. Traffic Complexity Management & Separation Management Services

(115) The primary focus of ERASMUS concerns the management of traffic complexity and separation. This function is carried out by the Service Provider up to 15 minutes prior to traffic entering its area of responsibility. “Traffic Complexity Management” is the attempt to optimise traffic distribution and reduce traffic complexity by applying:

- Delay mechanisms (e.g., miles in trail for specific destinations or exit points),
- Smoothing of traffic to segregate departures, arrivals and over-flights, and
- Trajectory alteration to reduce crossing traffic complexity in sectors.

(116) The Traffic Complexity Management (TCM) function will enhance the sector controller’s ability to safely and consistently handle high levels of traffic with acceptable levels of workload. The increased predictability of traffic that results from the 4D plan and target driven processes will permit through-sector and sector entry and exit planning to be accomplished well in advance of the aircraft’s entry into the sector, and will provide efficient spacing between aircraft.

(117) The pilot will be able to comply with spacing and sequencing instructions provided by the TCM function by using the traffic displays and automated support mechanisms that are linked to the flight management system. Furthermore, the 4D plan may include airline specific preferences for each flight. These preferences would then considered by the TCM function when modifying

an aircraft's trajectory.

(118) At the controller's tactical workstation, the system will present a level of information appropriate to their tasks. This information will be carefully filtered and prioritised to take full advantage of the controller's competencies in:

- Traffic assessment, and
- Traffic monitoring.

(119) ASAS procedures may be applied en-route to exploit the pilot's ability to manage the 4D plan while the pilot continues to maintain their specific spacing in the traffic flow.

(120) The controller will be responsible for transitioning traffic to new profiles and amending 4D plans in the event of scenario changes implemented by the Network Manager and/or Local Traffic Manager.

8. TARGETED ATM PERFORMANCES REQUIREMENTS

8.1. Key Performance Areas

(121) The ERASMUS project re-uses the KPA framework defined by SESAR [6][9] based on the 11 KPA identified by ICAO. No KPA is discarded and the KPA framework is the basis for the validation of the project. It is worth noting that ERASMUS is focused on the enroute airspace and improving its capacity, efficiency, and safety.

	Expectation	***SESAR Description* and application to ERASMUS**
Societal	Safety	*Safety is the highest priority in aviation, and ATM plays an important part in ensuring overall aviation safety. Uniform safety standards and risk and safety management practices should be applied systematically to the ATM system. In implementing elements of the global aviation system, safety needs to be assessed against appropriate criteria, and in accordance with appropriate and globally standardized safety management processes and practices.* The ERASMUS applications address the current ATM Barrier Model and incorporate the existing safety standards and management procedures.
	Security	*Security refers to the protection against threats, which stem from intentional (e.g. terrorism) or unintentional (e.g. human error, natural disaster) acts affecting aircraft, people or installations on the ground. Adequate security is a major expectation of the ATM community and of citizens. The ATM system should therefore contribute to security, and the ATM system, as well as ATM related information, should be protected against security threats. Security risk management should balance the needs of the members of the ATM community who require access to the system, with the need to protect the ATM system. In the event of threats to aircraft or threats using aircraft, ATM shall provide responsible authorities with appropriate assistance and information.* The ERASMUS applications re-use the technical enablers that take into account protections against threats and that minimise the occurrence and consequences of human errors.
	Environment	*The ATM system should contribute to the protection of the environment by considering noise, gaseous emissions, and other environmental issues in the implementation and operation of the global ATM system.* The ERASMUS area of investigation is limited to the en-route airspace. The environmental sustainability of this airspace is mainly driven by gas emissions and fuel consumption. Most of the ATM impacts on the environment are linked to flight efficiency.
Operational	Cost Effectiveness	*The ATM system should be cost-effective, while balancing the varied interests of the ATM community. The cost of service to airspace users should always be considered when evaluating any proposal to improve ATM service quality or performance. ICAO guidelines regarding user charge policies and principles should be followed.* The costs of the ERASMUS implementations will be evaluated and will be compared to the cost savings incurred during operations.

	Expectation	*SESAR Description* and application to ERASMUS
	Capacity	*The global ATM system should exploit the inherent capacity to meet airspace user demand at peak times and locations while minimizing restrictions on traffic flow. To respond to future growth, capacity must increase, along with corresponding increases in efficiency, flexibility, and predictability while ensuring that there are no adverse impacts to safety giving due consideration to the environment. The ATM system must be resilient to service disruption, and the resulting temporary loss of capacity.* Improving the en-route capacity and possibly the network capacity is a key objective of the ERASMUS project. Improvements to the overall network capacity may also result from these efforts..
	Efficiency	*Efficiency addresses the operational and economic cost-effectiveness of gate-to-gate flight operations from a single-flight perspective. Airspace users want to depart and arrive at the times they select and fly the trajectory they determine to be optimum in all phases of flight.* Flight efficiency during en-route operations will be optimised by minimising the number and magnitude of tactical interventions necessary for separation assurance.
	Flexibility	*Flexibility addresses the ability of all airspace users to modify flight trajectories dynamically and adjust departure and arrival times thereby permitting them to exploit operational opportunities as they occur.* ERASMUS will have no negative impact on operational flexibility. While actions will be based upon minor speed adjustments which could potentially inhibit dynamic speed changes, these adjustments will be limited to a small segment of the trajectory and are implemented only when necessary.
	Predictability	*Predictability refers to the ability of the airspace users and ATM service providers to provide consistent and dependable levels of performance. Predictability is essential to airspace users as they develop and operate their schedules.* The ERASMUS applications will enhance the predictability of en-route operations by synchronising trajectories commanded by air and ground, and by improving the accuracy of air and ground trajectory predictions.
Enabling	Access and Equity	*A global ATM system should provide an operating environment that ensures that all airspace users have the right of access to ATM resources needed to meet their specific operational requirements; and ensures that the shared use of the airspace for different airspace users can be achieved safely. The global ATM system should ensure equity for all airspace users that have access to a given airspace or service. Generally, the first aircraft ready to use the ATM resources will receive priority, except where significant overall safety or system operational efficiency would accrue or national defence considerations or interests dictate by providing priority on a different basis.* ERASMUS will have no negative impact. Access restrictions to the en-route airspace are not anticipated at this stage of the project. However, limitations might be justified during the transition period to encourage operators to upgrade their equipment.
	Participation	*The ATM community should have a continuous involvement in the planning, implementation, and operation of the system to ensure that the evolution of the global ATM system meets the expectations of the community.* Three "Users Forums" will be organised during the definition phase of

	Expectation	*SESAR Description* and application to ERASMUS
		ERASMUS project. The implementation of the ERASMUS concepts is based on the active involvement of ANSP pilots and aircraft operators.
	Interoperability	*The ATM system should be based on global standards and uniform principles to ensure the technical and operational interoperability of ATM systems and facilitate homogeneous and non-discriminatory global and regional traffic flows.* To the greatest extent possible, the ERASMUS applications will make use of the technical enablers and architecture designs proposed by SESAR.

8.2. ATM Targets

(122) Significant sector productivity gains are anticipated even during the initial technology transition period. These gains in capacity will most likely be used to address the anticipated increase in overall traffic. In the event that capacity meets demand, ERASMUS could be used to improve the cost-effectiveness of air operations.

(123) SESAR stated [8] that the main limitation of en-route capacity is the workload of the tactical controller. The ERASMUS project investigates several innovative applications that could ease the transition to a more automated ATM system.

(124) The following table lists the targets of the project for each KPA.

	Expectation	ERASMUS targets
Societal	Safety	Maintain or improve current level of safety.
	Security	Assess security issues related to the data link enabler.
	Environment	Assess environmental impacts during Human-in-the-loop experimentations Linked to flight efficiency.
Operational	Cost Effectiveness	Improve controller’s productivity in en-route sectors.
	Capacity	Improve en-route capacity: +20% in 2015 (w/ current airborne equipment) +50% in 2020 (w/ new generation FMS) Maintain and possibly reduce the amount of en-route delays. Airport and Approach capacity/delay is not considered.
	Efficiency	Preserve as much as possible the executed trajectory. Manage slight and smooth deviations to avoid tactical intervention (Prevent vectoring control actions through minor speed adjustments).
	Flexibility	Limit as much as possible the freedom to change a speed.
	Predictability	ERASMUS copes with the executed Business Trajectories and reinforces the predictability by synchronising air and ground trajectories
Enabling	Access and Equity	No access limits are anticipated. Transparency-driven project.
	Participation	Three interactive “Users Forums” organised to capture stakeholders’ feedback.
	Interoperability	Assess interoperability for a seamless transition.

8.3. Solution, KPA and Performance Tractability

Main solution: Complexity Management

What it means: Complexity management is a function within a multi-sector area that manages traffic to assure that the controller can manage the traffic safely and efficiently.

Enablers:

- Complexity detection and resolution
  - 4D trajectory prediction
    - More precise weather forecast
  - 4D trajectory contracting
  - Trajectory negotiation between air and ground
- FMS 4D technology with levels of longitudinal containment, 4D contract
- Data-Link
- SWIM for distribution of constraints
- NOP

Contribution to Performance:

Safety:

- Avoidance of situations that increase the controller workload
- Sharing of highly precise 4D business trajectory between air and ground will reduce uncertainty
- Air/ground data link reduces misinterpretations
- Complexity management assures preplanning of traffic for efficient spacing assurance

Capacity:

- Effective use of human mental resources
- Reducing controller workload allows for additional flights
- ANSP can operate close to the system’s limits, as exceeding limits will be prevented

Cost-effectiveness:

- Airspace users can choose the trajectories closest to their business needs and will still be compliant with complexity management actions.
- ANSP will make optimum use of resources
- Less controller workload allows additional traffic
- Flown trajectory will be closest to optimum profile

Flexibility:

- Not Applicable

Predictability:

- More accurate data available
- Aircraft will have a better containment. This will improve predictability which, in turn, increases system capacity

Environment:

- More optimum trajectories allow reducing the environmental impact of individual flights (trajectory optimum profile reduces fuel burn)

9. SUBLIMINAL MODE OF OPERATIONS

9.1. Objectives and Scope

(125) The subliminal Mode of Operations will use the “Traffic Complexity Management” service. This application will be located at a strategic level within the Multi Sector Planning (MSP) function. It aims at reducing the traffic complexity in a manner that is transparent to the sector controller. In contrast to the current MSP function (i.e. C-ATM, Gate-to-Gate), the subliminal application performs minor adjustments that are not perceivable by the sector controller, in a fully automated closed-loop.

(126) The information flow between the ERASMUS System (i.e., the MSP function), the aircraft/pilot, and the CWP/controllers, is presented in the diagram below (see Fig. 12).

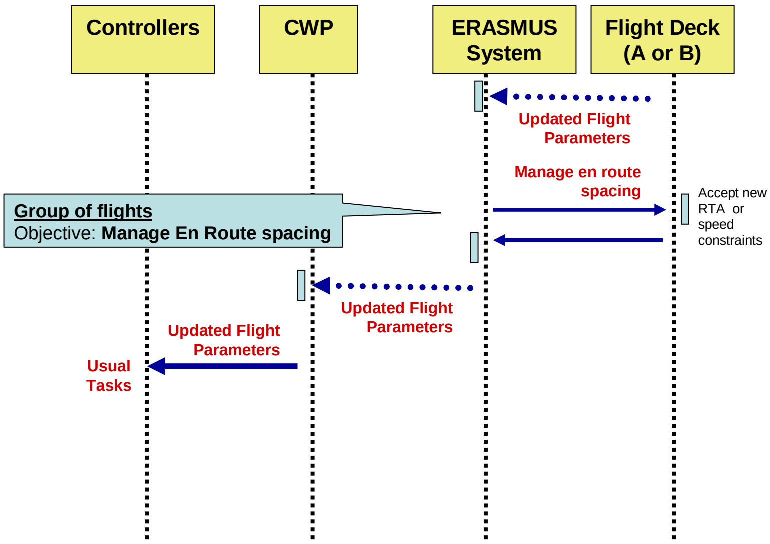

Figure 12 – Sequence Diagram

9.2. Technical Architecture

(127) From a technical point of view, the subliminal control application is built on a co-operation between air and ground systems. It takes full advantage of airborne flight management system and air/ground communication facilities (Fig. 13).

(128) For the airborne part, the system architecture relies on two main functions:

- A Trajectory Prediction (TP) function that provides an estimated 4D trajectory computation.
- A Trajectory Contracting function that allows the ATC ground system to set speed or time constraints on the 4D flight profile.

(129) On the ground side, the system is built on the following functions:

- A flight plan route consistency function that ensures that the airborne 4D trajectory is consistent with the ATC 4D-trajectory computed from flight plan and inter-centre coordination information.
- A Ground Trajectory Prediction function that computes the traffic at an horizon time of about 20-30 minutes.
- A Conflict Detection function that identifies the flights on which controllers are likely to intervene if no subliminal actions were performed.
- A Conflict Resolution function that implements a conflict resolution strategy based on minor speed alterations or RTA constraints.

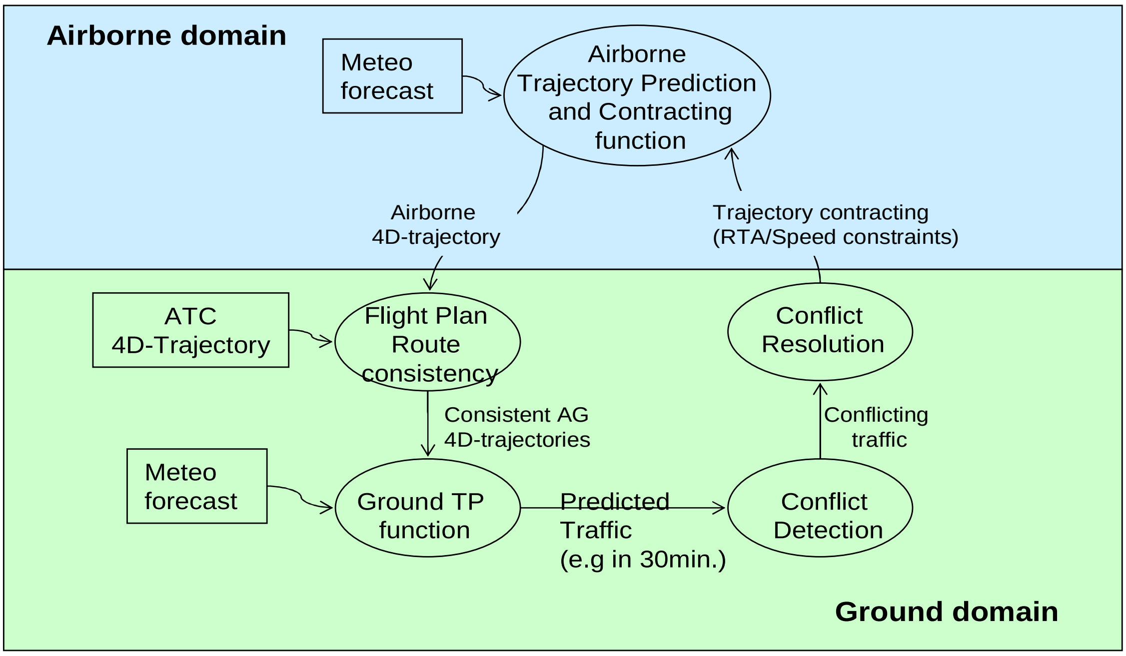

Figure 13 - Subliminal Control application – Functional Architecture

(130) The high-level processing performed by these functions description is given below (see Figure 14).

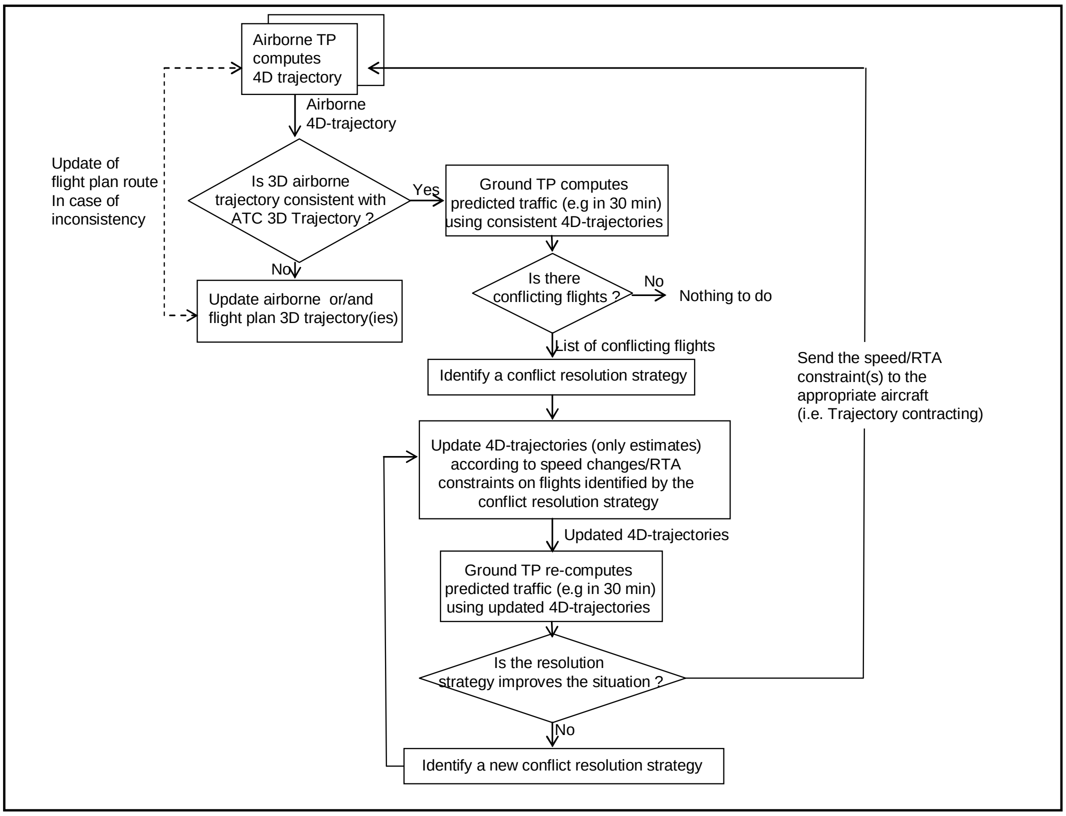

Figure 14 - Subliminal Control application processing

9.3. Anticipated Constraints

9.3.1. Consistency

(131) Each subliminal control action aims at reducing the perceived-risk situations within a sector. It is worth noting that the overall system must be considered for wide areas covering at least one ACC and perhaps even the entire European upper region. In other words, ERASMUS cannot focus on only one sector. Rather, it is a multi-sector process that continuously monitors and reassesses the traffic situation and updates the control actions accordingly.

(132) This type of management action is efficient only if the effects in "upstream" and "downstream" sectors are taken into account. In cases where a single sector is managed by one CWP (a common operational case, See Figure 13), the subliminal control action on a flight takes place before the integration of the flight within one or two upstream sectors. Before being issued, the effects of a subliminal control directive are evaluated and the managed flights must not create a perceived-risk situation in the upstream and downstream sectors.

(133) The trajectory of the managed flight does not span the departure to arrival gates. It only considers the next en-route segment to be flown. The trajectory over the next 20 or 30 minutes is adjusted and synchronized to keep it free of conflict. This timeframe is limited by the accuracy of the data and by the need to preserve some minimum flexibility in managing the separations.

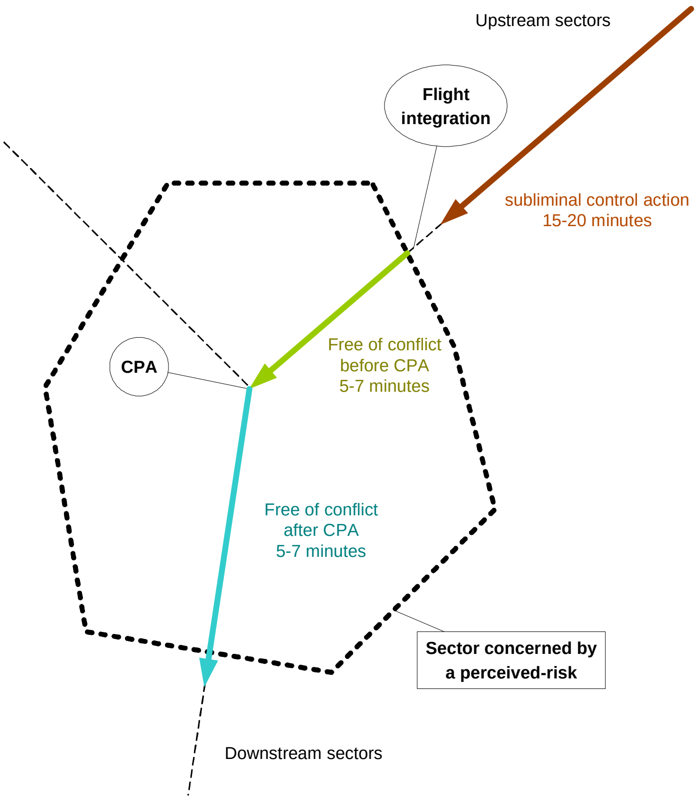

Figure 24: Time frame of a subliminal control action

9.3.2. Interferences

(134) There are two sources of interference that can interrupt or negate an ERASMUS action:

- Pilot requests;
- Controller actions (e.g., manual conflict resolution; weather; emergency; etc).

(135) Since controller actions that involve conflict resolution are likely to occur frequently, ERASMUS concentrated on problem created by this situation.

(136) Because a time horizon of 15 minutes is required to initiate an ERASMUS action, these actions must be given in either a N-1 or N-2 sector. Since the actions are subliminal and not perceptible by the operator, it is completely possible that the controller can unwittingly interfere with a plane that is under ERASMUS control. Since the actions of the operators (i.e., controllers and pilots) take precedence over ERASMUS actions, the ERASMUS conflict resolution strategy will be interrupted. Optimising the number of successful ERASMUS actions must consider the following:

- In sector N-x, for aircraft under ERASMUS control with separations < 7 Nm, there is a very strong chance that the controller will issue a clearance that disrupts the ERASMUS solution.
- In the N-x sector, for aircraft under ERASMUS control with separations ranging between 7 - 14 Nm, the likelihood that the controller will issue a clearance that disrupts the ERASMUS solution varies from more likely at 7NM to less likely at 14NM.

- In the N-x sector, for aircraft under ERASMUS control with separations > 15 Nm, there is a very small chance that the controller will issue a clearance and disrupt the ERASMUS solution.

9.4. Operating Methods

(137) Three main processes have been identified in the en-route phase of a flight :

- Aircraft process,
- Traffic complexity process, and
- Separation process.

(138) The aircraft process is comprised of the 4D Flight Plan Management, the Tactical Control of the aircraft and Collision Avoidance. For individual aircraft, the 4D flight plan management focuses on execution and improved predictability with regard to the 4D business trajectory. Spacing operations as well as the execution of tactical instructions from the ground system are summarised in Level 2 process B (see Figure 17). Collision Avoidance is comprised of independent safety net systems like ACAS.

(139) One of the essential goals of ERASMUS is to support a layered planning system that connects planning from the Air Traffic Flow Management (ATFM) level to the control of the aircraft in a sector. In order to accomplish this, the sector Planning Controller must be given a more active role, and a new planning layer added through the Multi Sector Planner (MSP).

(140) The traffic Complexity Management Process contains the ground component of the 4D Flight Plan Management, as well as all of the processes related to sector management. The main objective of Flight Plan Management is to clear the aircraft according to the 4D business trajectory. It also aims to minimise flight path deviations due to anticipated solutions of complex traffic patterns within the area of responsibility. The traffic Complexity Management Process refines the overall planning from the previous ATFCM processes (Local Flow Management) at the sector or multi-sector level. Because these processes manage complexity and provide traffic solutions, tactical separation tasks should be less demanding.

(141) The separation process handles sector management and provides ground safety net functionality. The separation management process ensures safe traffic flow. It is also responsible for traffic planning and tactical intervention while an aircraft is under the controller’s responsibility. The co-ordination of flights and handover procedures (i.e., the transfer of communication and control) to the adjacent sector will be accomplished via data-link and system-supported silent transfer of flights. The ground safety net processes contain functions like Short Term Conflict Alert.

(142) Figure 17 and Table 6 provide a summary of all Level 1, Level 2 and Level 3 processes.

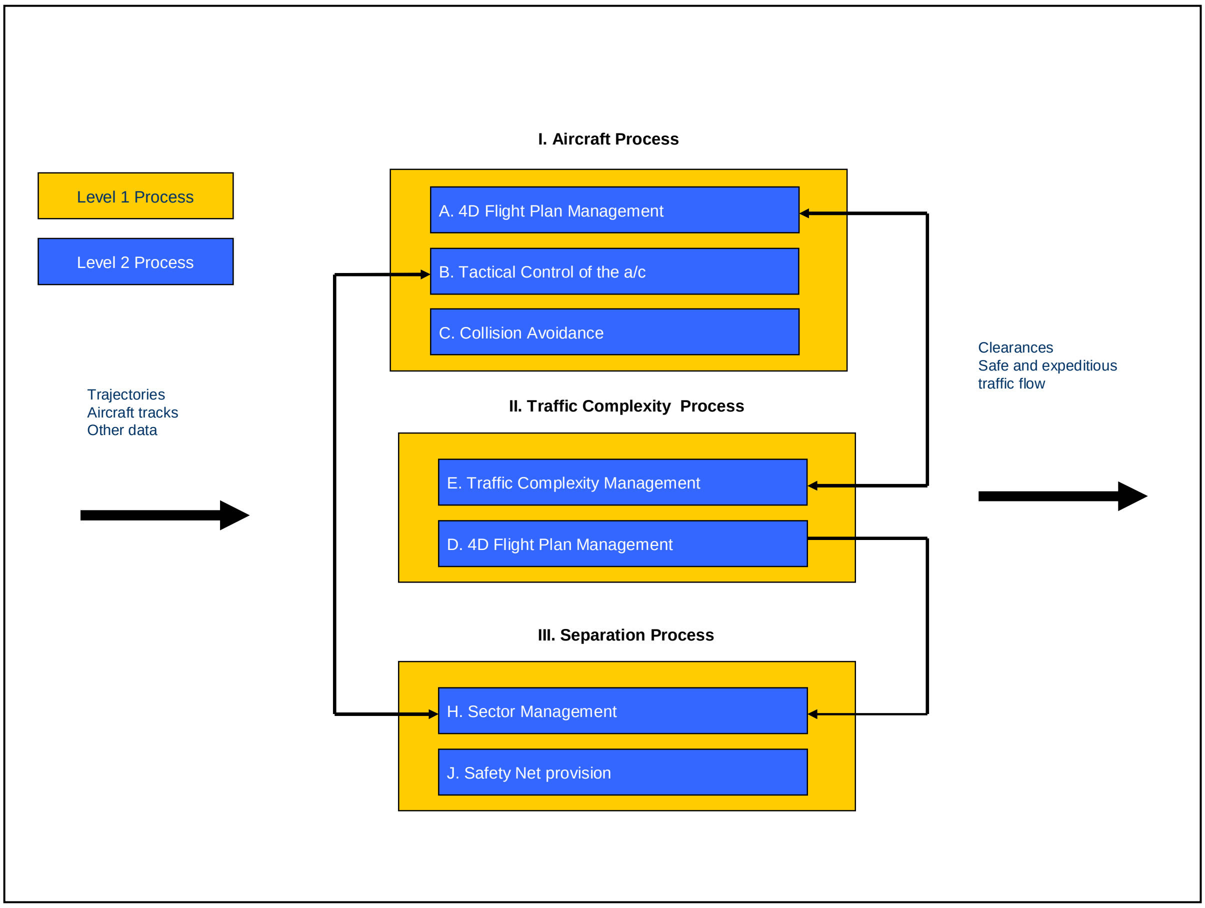

Figure 17 - Overview of Level 1 and Level 2 Processes

Level 1 Processes	**Level 2 Processes**	**Level 3 Processes**	**Remarks / Enablers**
I. Aircraft process	A. 4D flight plan management of the aircraft	1. Trajectory execution	
		2. Trajectory conformance monitoring	
		3. Trajectory revision	
	B. Tactical control of the aircraft	4. Execution of ERASMUS Spacing	Spacing management, closed loop
		5. Execution of other tactical instructions	Separation management, open loop instructions
	C. Collision avoidance	6. ACAS, GPWS	Fully independent, not part of ERASMUS improvements
II. Complexity process	D.Traffic complexity management for area of responsibility (refinement of the overall planning	7. Monitoring of traffic	

	goal at the local level; Planning role, around 15 minutes before sector entry, "ease" separation process)		
(expeditious traffic flow)		8. Complexity management	Tool support: MTSA; related to the traffic in the sector(s)
		9. Planning of traffic	Complexity resolution and replanning, miles-in-trails spacing, Level adjustment, route change
	E. 4D flight plan management of individual aircraft	11. Trajectory revision	Allow a/c to follow the revised cleared trajectory
		12. Trajectory Conformance monitoring	Only refers to 4D equipped (origin: FLIPCY 4D being further developed regarding ground actions)
III. Separation process	H. Sector management for area of responsibility	14. Monitoring of traffic	Build and maintain mental picture (cognitive process)
(safe traffic flow)		15. Conflict detection	NTCD
		17. Planning of traffic	Identify (refine) solutions for getting the traffic "safe" through the sector
		18. ASAS spacing applications	ATC autopilot
		19. Tactical intervention	Conflict resolution, other clearances
		20. Co-ordination/Transfer management	Data link services, silent transfer of flights Handover procedures SYSCO, standing agreements
	J. Safety net provision	21. STCA, MSAW, etc.	

Table 6 - ATM Processes "ATC En-Route"

9.4.1. Scenarios

(143) The scenario described hereafter illustrates the subliminal control application in an operational situation. The main actors identified are:

- Air side:
    - the pilot,
    - the equipment of the cockpit (e.g. FMS, data link interface).
- Ground side:
    - the ground system(s) responsible for the aircraft,
    - the ERASMUS system.

(144) The proposed operational situational is as follows (Fig. 18):

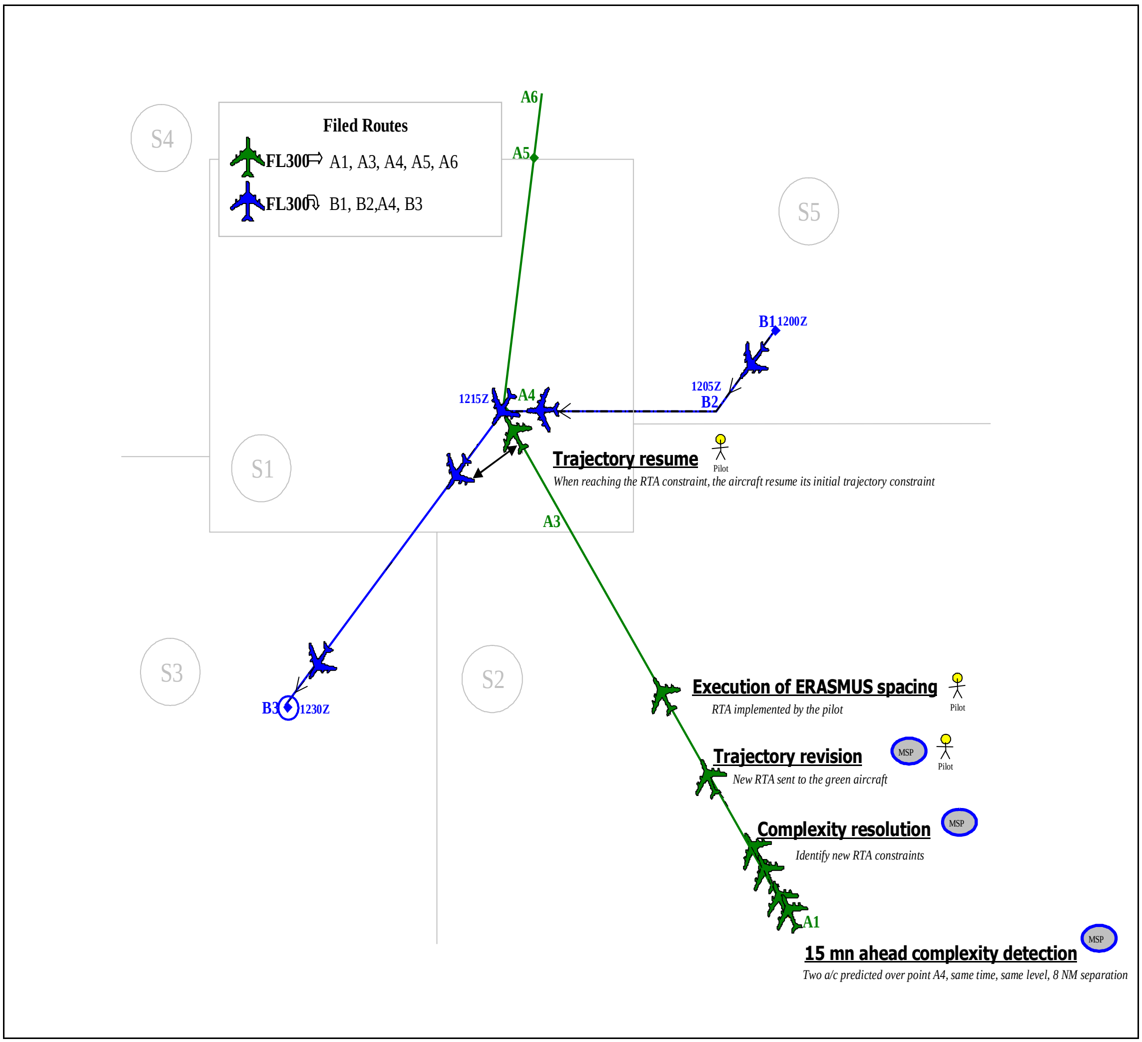

Figure 18 - Example of Operational scenario

(145) Two flights Green and Blue are considered. The flight Green is controlled by the ACC centre S2, the flight Blue is controlled by the ACC centre S5 and they are converging within a sector of the ACC centre S1.

(146) Based on this scenario, the following sequence of exchanges and processes between the main actors are as follows:

Traffic Complexity Management *Monitoring of Traffic*	Flights Green and Blue and all other equipped aircraft downlink regularly their position and predicted trajectory to the ground system through ADS-B.
Traffic Complexity Management *Complexity Management*	Each ACC ground system uses the air trajectory prediction to consolidate its own ground trajectory prediction and send to the ERASMUS system both the raw aircraft trajectory prediction and the air/ground consolidated trajectory prediction.

Traffic Complexity Management *Planning of Traffic*	The ERASMUS TP computes the traffic with a “look-ahead” time of 15 minutes. The CD function identifies the conflicting aircraft and the CR function identifies a strategy to solve the conflicts. In this case, a complexity problem in ACC centre S1 is detected between aircraft Green and Blue. The CR function identifies the point on which the RTA constraint will have to apply and the kind of RTA constraint (e.g. “CROSS RTA_PT1 AT 13:21” for aircraft Blue and “CROSS RTA-PT2 AT OR BEFORE 13:18” for aircraft Green). The ERASMUS communication function identifies that aircraft Blue is currently controlled by ACC centre S5 and that aircraft Green is controlled by ACC centre S2 to send the RTA clearances to the appropriate ATC centre by ground-ground communication.
Traffic Complexity Management *Trajectory Revision*	On reception of a clearance coming from ERASMUS, the ATC ground system sends the clearance to the aircraft Green without informing the controller in charge of the flight.
Aircraft Process *Trajectory Revision*	When the pilot receives the clearance, he/she sends back a STAND-BY message to inform the emitter that he/she needs some time to perform the required action. He/she then verifies that the RTA constraint can be implemented. In the positive case, the pilot sends a WILCO and inserts the new RTA waypoint and its associated time constraint in the FMS. (see Figure 19).
Aircraft Process *Execution of ERASMUS spacing*	This RTA will update the predicted trajectory that is sent periodically to the ground ATC systems. The ERASMUS system will be able to detect that the RTA has been applied when the new RTA waypoint with its estimated time will be received from the aircraft.
Separation Process *Monitoring of Traffic*	Controllers are not aware of the subliminal control action. The speed adjustments of flight Green are not detected by the controllers of the ACC S2 (speed change below the threshold of perception). The controllers keep controlling flight Green (S2 ACC) and Blue (S5 ACC) as usual.
At this point, Green from the south is 15 minutes from the S1 boundary and is proceeding as planned.	
Separation Process *Monitoring of Traffic* *Conflict Detection*	At the integration of Flights Green and Blue, the controller from the ACC centre S1 will detect that the separation margins with other flights are large enough to consider flights Green and Blue as free of conflict. The check is easy and quite immediate: attention resources to analyse an unreliable situation have been saved.
Separation Process *Monitoring of Traffic*	Controllers keep on performing their usual tasks for flights under their responsibility, flights X and Y do not require a specific management.
Aircraft Process Execution of other tactical instructions (resume navigation)	When reaching the RTA_PT, the RTA constraint is terminated and the aircraft Green can pursue its flight at its speed convenience.
The complexity resolution manoeuvre is successful and separation is assured between Green and Blue. Green passes behind and then resumes own navigation to point A6. Both aircraft continue, with the controllers (S1) performing the other continuous tasks previously mentioned.	

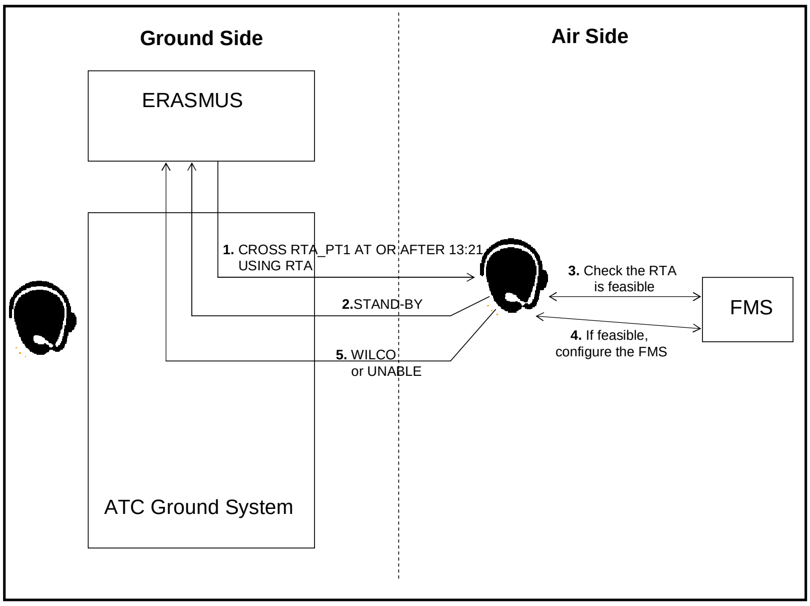

Figure 19 - Illustration of CPDLC exchanges

9.4.2. Aircraft Process

9.4.2.1. 4D Flight Plan Management of the aircraft

(147) During the flight, the aircrew executes the 4D business trajectory using the FMS managed mode, steering the aircraft along the lateral path and the vertical profile to TTA (i.e., FMS input corresponding to the TTA).

(148) If the wind at aircraft's current position is different from the forecasted wind (i.e., input by the aircrew for specific waypoints), the FMS extrapolates wind change for the next waypoints and re-computes the trajectory. If the new ETA does not correspond to the RTA, the FMS automatically adjusts the speed to meet the RTA.

(149) The FMS will re-compute the predicted trajectory periodically and upon flight plan or context changes. It will monitor the how closely the predicted trajectory matches the cleared trajectory.

(150) The trajectory revision process is strategic in that it anticipates potential traffic complexity issue. The 4D trajectory revision is initiated by the ground system. It provides targets for active speed control that will allow the aircraft to meet a specified crossing time at a selected waypoint (e.g., ERASMUS spacing manoeuvres). This crossing time is up-linked to the aircraft. When the pilot enters the restriction into the FMS, it will use the RTA guidance function to comply with the assigned time.

9.4.2.2. Tactical control of the aircraft

(151) The aircrew identifies that the aircraft is able to meet the new RTA (trajectory revision process) and activated onboard and automatically down linked for information dissemination. The

different trajectory revision states are the following:

- **Starting an ERASMUS action**

  Approximately fifteen minutes ahead of a predicted loss of separation between two or more flights, the ground based ERASMUS system will develop a set of actions that should eliminate the potential loss by contracting a portion of the trajectory of the aircraft. ERASMUS will create a RTA clearance that will be sent to the relevant aircraft.

  1) The pilots of the flights involved will be notified of the proposed ERASMUS action.
  2) The pilots will determine if the ERASMUS action can be accepted.
  3) The pilots will either accept or reject the proposed ERASMUS action.
  4) The pilots will command the FMS to either follow or reject the proposed ERASMUS action.
  5) The pilots will verify that ERASMUS action has been properly programmed.
  6) The pilots will monitor the aircraft's performance to assure that ERASMUS action is being carried out correctly by the FMS.

  During the ERASMUS spacing execution, the FMS re-computes the trajectory prediction.

- **Ending an ERASMUS action**

  Once the ground based ERASMUS system has determined its action has managed the spacing criteria, ERASMUS will send a release message to the relevant aircraft. The pilot will verify that the parameters of the ERASMUS actions are maintained until the Point of Release is received, at which time the aircraft may return to its flight planned values.

  1) At the Point of Release, the pilots of the impacted flight(s) will be informed that they may return to normal operations.
  2) The pilots will determine if ending ERASMUS action can be accepted.
  3) The pilots will either accept or reject the ending of the ERASMUS action.
  4) The pilots will command the FMS to either complete or reject the ending of the ERASMUS action.
  5) The pilots will verify that that the selected action has been properly programmed into the FMS.
  6) The pilots will monitor the aircraft's performance to assure that the selected action is being carried out correctly.

- **Interrupting an ERASMUS action**

  The possibility of interrupting an ERASMUS action, just like the requested actions by a human ATCo will always be possible. Such interruptions can be based on the initiative of ERASMUS, the ATCo, the pilot, or one of the technical systems. As soon as there is need to modify the parameters of flights, the ERASMUS action can be stopped and appropriate aircraft will be immediately notified.

  The pilots will monitor that the parameters of the ERASMUS actions are maintained until an interruption request is received, at which time the aircraft may return to its previous flight plan clearance.

  1) At the interruption, the pilots of the impacted flight(s) will be informed that they may return to normal operations.
  2) The pilots will need to determine if interrupting the ERASMUS action can be accepted.
  3) The pilots will either accept or reject the interruption of the ERASMUS action.

4) The pilots will command the FMS to either follow or reject the interruption of the ERASMUS action.
5) The pilots will verify that that the proper action has been properly programmed into the FMS.
6) The pilots will monitor the aircraft's performance to assure that the selected action is being carried out correctly.

(152) The aircrew will have additional support tools:

- Ergonomic FMS interface

  Until technology makes it possible for ERASMUS actions to be automatically entered into the aircraft's FMS (where it would await pilot approval), a highly efficient manual method will need to be developed that will minimize time delays and the potential for keying errors. Given that the traditional FMS requires an interaction-style that is dictated by the needs of the system rather than the needs of their human operators, an ergonomic ERASMUS/FMS interaction syntax that is optimised for implementing the ERASMUS messages would reduce reaction times (i.e., entry), reduce pilot/FMS interaction errors, and subsequently enhance overall ERASMUS effectiveness.

  The prototype ERASMUS FMS interface will be built upon technology developed by Honeywell. This system uses the standard ATC clearance syntax as the basis for creating the FMS input. Therefore, ERASMUS action clearances will map directly into the airborne FMS. Because the system input logic is based upon a paradigm that is well understood by all pilots, it will significantly reduce the time needed to enter the clearance and the probability of input errors. It will also significantly reduce the training time required to use the new features and ease the pilot's cognitive burden.

- Four Dimensional Navigation Display Format

  It has long been recognized that flight crews develop mental models of the traffic situation based in part on information gleaned from the VHF "party line[5]". Using this source of information, they can infer the amount of traffic in the area and its general location. In addition, pilots can identify significant traffic issues based the amount and type of vectoring being given to other aircraft. Verbal communication between controllers and pilots is likely to occur less frequently in an ERASMUS system. Furthermore, the cause of the ERASMUS action may be several sectors (and thus radio frequencies) away. These factors will make it more difficult for the flight crews to develop an accurate mental model of the traffic situation. Thus, it may often be difficult for the flight crew to determine the consequences of accepting or rejecting a requested ERASMUS action (e.g. if you do not accept you will have to hold for five minutes at the XYZ intersection). Therefore, a method of providing this type of relevant information for use by the flight crew in their decision making must be identified. For example, an ergonomic 4D display format that elucidates the consequences of the ERASMUS action could facilitate the development of an accurate mental model of the traffic and of the consequences of accepting/rejecting an ERASMUS action.

- Four-Dimensional Weather Display Format

  The partial loss of the "party line effect" (i.e., the flight crew's ability to listen in on the ATCo's voice communications with other aircraft in the area) may also impact the flight crews understanding of how future weather could impact their future performance and thus their ability to meet ERASMUS actions. Currently, when flight crews hear (via the party line) other aircraft being vectored around weather they will expect and plan for similar

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[5] It has been labelled the party line effect, because all the pilots on a local frequency can hear both sides of most air-to ground & ground to air conversations.

vectoring. Vectoring can be the result of weather, as well as second order effects (e.g., vectoring due to traffic conflicts created or magnified by the weather).

Verbal communication between controllers and pilots is likely to occur less frequently in an ERASMUS system. Furthermore, the cause of the ERASMUS action may be several sectors (and thus radio frequencies) away. These factors will make it more difficult for the flight crews to develop effective mental model of the meteorological situation. Therefore, the flight crew should be provided with a tool that would facilitate the creation of an accurate mental model of how distant weather is impacting the flight (e.g., rerouting, delays, its position in the traffic flow). This could facilitate flight crews' acceptance of and compliance with ERASMUS actions.

It is conceivable that ERASMUS could be forced into continuously issuing new actions in an attempt to solve a continuously changing traffic conflict situation (e.g., a moving gap in a line of thunderstorms). Furthermore, the cause of the conflict may be two or three sectors away, even beyond the onboard weather radar's range, making it very difficult for the pilot to form an accurate understanding of the situation. A weather visualization aid - like the NASA AWIN tool - could assist flight crews better understand the meteorological forces that are impacting the air traffic flow. Such information could support the flight crew's meteorological situation awareness and thus make ERASMUS safer and more efficient from a systems point-of-view.

9.4.2.3. Collision Avoidance

(153) The Airborne Collision Avoidance System (ACAS) will, as it does today, act as a last resort, independent airborne safety net to prevent collisions with other aircraft. ACAS issues traffic alerts to inform the flight crew about traffic in the vicinity, and it commands evasive manoeuvres in the vertical plan (i.e., Resolution Advisories - RA) to prevent a possible collision between aircraft. The independence of ACAS from ERASMUS spacing must be assured.

(154) Under current regulations, even when an aircraft is operating under direct control of an ATCo, any time an aircraft is in a visual meteorological conditions (VMC) the flight crew retains its legal responsibility to "see and avoid" other traffic and hazards. Therefore, the flight crew must maintain a visual check to assure that they preserve safe and legal clearances from all hazards, independent of vectors given to them by an ATCo or ERASMUS. Thus, if a clearance from an ATCo or ERASMUS would result (in the opinion of the flight crew) in the loss of legally required separation, the flight crew has the duty to question the clearance, and if necessary, reject it.

(155) To comply with this requirement, anytime the aircraft is operating in VMC, both pilots are expected to continually clear (i.e., visually check) the airspace for aircraft and other potential hazards. In large crew stations, where the pilots sit side-by-side, it is necessary to divide the responsibility to clear the sky around the aircraft, because of the difficulties of adequately scanning the sky on the other side of aircraft from where the pilot is sitting. This is in part due to window size, location, and distance (which can significantly reduce the angle of sky subtended compared to the pilot sitting immediately next to it). On those occasions when one pilot must go heads-down (i.e., attend on to the something inside the cockpit), that pilot verbally informs the other pilot, that he/she is heads-down, so that the other pilot can visually cover that area of the other pilot would normally be clearing.

(156) It should also be noted that once ADS-B becomes available to flight crews, their responsibility to "sense and avoid" will more than like include the use of ADS-B data, in addition to their traditional look out the windows to "see and avoid."

9.4.3. Traffic Complexity Process

9.4.3.1. Traffic Complexity Management

(157) Air Traffic Flow Management provides a strategic planning service several hours before the aircraft enters the air traffic control sector. In contrast, the Tactical Controllers are operating only a few minutes ahead of potential aircraft conflicts. The purpose of a Multi Sector Planner function is to offer medium-level strategic rather than tactical solutions to overcome traffic complexity. Aircraft trajectories would be planned over several sectors. The aim is to reduce the workload of sector controllers and optimise trajectories for suitably equipped aircraft. Conflict resolution remains an ATC responsibility.

(158) The aim of this process is to detect traffic situations that may require complex traffic resolutions. Relying on the input from the Monitoring of Traffic process, it anticipates future situations and events through a continuous analysis of the evolving traffic, based on flight plan and radar data. An assessment of this traffic for future control actions will take place. Abnormal situations or equipment failures will demand special attention. This process has to determine whether an intervention is required or not. If no action is required the problem will be disregarded. If an action is required the Planning of Traffic process will be invoked.

(159) This process occurs continuously and in parallel with other processes. It is triggered by specific traffic patterns that are considered “complex” by a human operator.

(160) Depending on the time horizon, support for the evaluation of expected traffic situations will be provided in form of the complexity Predictor.

(161) Because of more accurate data inputs into the sector planning tools, risks posed by traffic complexity and separation infringement will be anticipated and solved in a more timely fashion by the MSP function, leading to a decrease in traffic complexity and conflicts.

(162) The Multi-sector planning function will:

- provide medium-term planning (e.g., 15 minutes) for 4D controlled flights,
- reduce traffic complexity in preparing trajectory modification to be implemented by the sectors,
- optimise trajectories as appropriate, and
- provide sector complexity and workload information to the sector’s controllers.

(163) The MSP function will be fully automated. An operator will be provided with suitable interfaces with which to supervise the machine function, but it will not require any human intervention except in case of abnormal system behaviour.

9.4.3.2. 4D Flight Plan Management of individual aircraft

(164) The strategic 4D business trajectory revision process will be as follows:

- The ground system (MSP function) anticipates the need for intervention and determines a new constraint.
- The new RTA constraint is up linked by the MSP function.
- The new aircraft trajectory is down linked by the aircrew.

- The proposed aircraft trajectory is checked by the aircrew.
- The revised 4D trajectory is activated by the aircrew and automatically down linked for dissemination through the AOP.

(165) The trajectory proposed by the aircraft may meet the previously accepted RTA (e.g., the FMS speed adjustment is possible within the aircraft limits) or it may not. In this latter case, the RTA is revised, based upon a new trajectory and speed adjustment that is proposed by the FMS.

(166) The impact of the new RTA constraint on the TTA can be precisely calculated by the onboard FMS (i.e., the speed adjustment) whereas the ground TPS is only able to roughly assess the revision of TTA. That is, it can only determine whether it will be within or outside the TTA window, but it cannot assess the speed adjustment).

(167) This type of negotiation (i.e., issuing of a "counteroffer" TTA by the flight crew) is undesirable because of the additional workload it would impose on the controller and flight crew.

9.4.4. Separation Process

(168) ERASMUS will have minimal impact on the working tasks of the pilot. Indeed, from the pilot's perspective, ERASMUS actions will seem like the actions of a competent ATCO - distributing traffic in a way that guarantees the legally required separation between aircraft. In addition, the pilot can interrupt an ERASMUS action at any time, just as they can interrupt those issued by a human ATCO. The main principle is that both the controller and the pilot can interrupt an ERASMUS action in an effective and safe way.

(169) The Controller Working Position HMI will remain the same as no additional information (i.e. ERASMUS actions) will be presented to the sector controllers.

9.4.4.1. Separation Management

(170) This process will identify potential conflicts (i.e., infringements of separation criteria) by evaluating the relative positions and current and future intentions of aircraft within the defined airspace volume. Evaluations will be based on surveillance and trajectory data.

(171) The controller will continue to identify conflicting traffic using cognitive processes developed through training and experience. The system will:

- Preserve the controller's interest in the system. They will still be able to cope with the complexity and the variability of the control situations.
- Preserve the controller' job interest. They will not merely perform a supervisory role. Doing so would induce loss of skill, cause poor traffic awareness, and reduce the controller's ability to cope with unpredicted events.
- Preserve teamwork by facilitating a common representation of the traffic situation, by providing computer assistance for the analysis and tracking of identified problems, and by preparing and implementing solutions.

(172) The sector ATCo roles and tasks are:

Planning Controller (PC):

- The PC primarily performs short-term management of en-route sector traffic about 10 minutes before the traffic enters the sector. A secondary role is to provide assistance to the Tactical Controller (TC).

- The PC anticipates the evolving traffic situation in order to ensure an efficient routing of traffic through the sector. Traffic conflicts are managed through resolution, through the strategic creation of conflict-free trajectories, or through delegation to the tactical controller.
- After control is delegated to the sector's tactical controller, the role of the PC is to assist the TC, when required, until a transfer of control to the next sector.
- The main tasks of the PC involve monitoring the evolving traffic situation, sector-wide planning, integrating flights, and assisting the TC with executive control of the flight.

Tactical Controller (TC):

- The TC provides tactical traffic management in the en-route sector.
- The TC provides trajectory planning through the sector, monitors the traffic situation, resolves any outstanding situations and manages unexpected situations.
- The TC performs this executive control task using Radio/Telephone.

(173) ERASMUS will support more effective management by reducing traffic complexities. It will increase the accuracy of time information (ETO) available to the controller and to conflict detection tools. Making the FMS trajectory information available to ground systems will open up a new phase of system development.

9.4.4.2. Safety Net provision

(174) The Safety Net provision will be provided by a support tool called “Near Term Conflict Detection” (NTCD). This will detect conflicts between aircraft up to 6 minutes in advance for aircraft on open- and closed-loop trajectories. It will mainly support the executive control function.

(175) The system will support separation assurance by providing warnings of increasing urgency as the time of predicted loss of separation approaches. Warnings should not be provided until a certain level of probability is reached.

10. MTSA MODE OF OPERATIONS

(176) The MTSA (Medium Term Separation Assurance) function was previously identified as the “enhanced MTCD”. While the MTCD function only deals with detecting known conflicts, the MTSA provides information to the controller about aircraft separation situations in order to help them identify potential separation issues earlier.

(177) MTSA will provide information about the real-time traffic complexity in order to help the controller analyse the situation and make appropriate decisions. It will also provide information about aircraft separations provided by the ERASMUS technical system.

(178) The MTSA will facilitate appropriate decision-making because those decisions will be based upon more accurate data. However, the MTSA will not disrupt the controller's normal cognitive processes. A reduction of the number of tactical interventions is anticipated.

10.1. Service in Use

To Be Completed For Deliverable D2.2.2

10.2. Operating Methods

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11. ATC AUTOPILOT MODE OF OPERATIONS

(179) Using the MTSA, the controller will be able to elaborate a strategy and to decide whether to delegate the traffic situation to the system for management. ERASMUS will then employ minor adjustments to aircraft speed or rate of climb in an air/ground closed-loop.

(180) In comparison to the current ground system, an aircraft's en-route attitude and trajectory control can be delegated to the automatic pilot. The pilot can define flight parameters and then let the automation manage their control while retaining the authority to alter any flight parameter at any time. In other words, the pilot determines strategy while the FMS executes closed-loop tactical trajectory adjustments, some of which may not even be perceived by the pilot.

(181) However, it is important to note that ERASMUS will not infringe upon the authority - nor reduce the responsibility - of either the controller or the pilot. ERASMUS action will be limited to managing only the traffic delegated to the "ATC autopilot" function. Controllers will still be able to issue any classical clearances and the pilot will still be able to modify the flight plan after agreement with the controller.

(182) Any new responsibilities allocated to ERASMUS are the result of explicit delegation by the controller and each is acknowledged by the ERASMUS system. For example, a controller monitoring board could show the status of all sector traffic and indicate which aircraft are being handled by the controller and which have been delegated to ERASMUS for management.

(183) In the future, once the necessary data link and airborne software are available, the aircraft's onboard system could be given the responsibility for automatically assuring separation whenever possible, alerting the controller and the pilot as necessary. This would lead to a smooth and progressive transfer of separation monitoring from the ground based system to the airborne system. However, the system could continue to provide surveillance and alerting activities.

11.1. Service in Use

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11.2. Operating Methods

To Be Completed For Deliverable D2.2.2

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ANNEX 1 – HUMAN FACTORS : THEORITICAL MODEL

A 1.1. A new way to think about complexity

(184) The controller's task is to manage a dynamic, complex and safety critical system. Such systems are characterized by:

- Dynamism - the specifics of the situation change spontaneously (without direct operator input).
- Continuous momentum - it is not possible to stop the process to alleviate time-pressures.
- Interrelatedness - Complex linkages and interactions exist between system elements. The entire system may become disabled or completely cease to function if one or more elements are removed. The couplings between elements may be tight or loose, depending on the type of system, and therefore exert less or more influence on the system.
- Unpredictability - The consequences of acting upon the system are difficult to anticipate because elements may interact in unforeseen ways. This poses a high risk when the consequences of the actions are safety-critical.
- Opacity - the internal system behaviour is neither explicit nor directly accessible.

(185) One of the human operator's greatest strengths is their inherent ability to manage complex system and complex situations. However, this resource is limited by each individual's skill and capacity. Therefore, the goal of any proposed solution should be to reduce system complexity in order to remain within these limits. The first issue is to identify what makes a task complex.

(186) Until recently, the "opacity complexity" approach has been widely used in order to provide system transparency to the controller. These are a variety of different techniques that serve to inform the controller about certain risks (i.e., density and conflict management). However, this approach also presents some problems:

- Opacity: While this technique does provide the controller with a certain amount of insight into the system state, its use also disrupts the controller's normal cognitive activity cycle. It requires that the controller interrupt the current task (and its underlying cognitive flow) to reassess the situation, comparing and updating his or her mental picture of the current system state with that proposed by the new information (e.g. conflict detection). Ultimately, this technique does not yield any resource economies. That is, it does not reduce the controller's amount of work nor make that work any easier. Consequently, any proposed automation that endeavours to have a positive affect the ATM system must intervene outside the controller's normal task cycle.
- Risk: "Transparency" is the attempt to present to the controller more information in order to simplify their job. However, the complexity criteria remain poorly identified. Over the past decade, many projects have attempted to isolate and focus on two basic components: traffic density and conflict management. However, conflict management has proven to be very difficult to master. This is largely because traffic management algorithms often reach their solutions by reducing the problem to a only a single pair of interacting aircraft rather than as clusters of interacting aircraft. Because "conflict potential" and "aircraft density" are so tightly coupled, most algorithms struggle to sufficiently represent the complexity.

(187) In contract, the ERASMUS project proposes a new way of approaching the problem. In particular, any solution should:

- Preserve system opacity, and
- Identify new criteria to better capture system complexity.

(188) In a peculiarity of the human intellect, people are able to make effective decisions and take appropriate action even in situations without complete informational “transparency”. This comes from our ability to form effective mental models of a given situation based upon incomplete information. We use expert judgement, previous experience, and, when needed, “wild guesses” to fill in any gaps.

(189) If the ATM operational environment was completely understood, with the available information absolutely accurate and deterministic, a controller could successfully complete their tasks by making logical deductions based upon the available data. Expert judgments and interpretations would not be required as the controller tasks could be reduced to a “simple” processing capability.

(190) In this case, the controller would be managing a complicated system, but not a complex one. The main difficulty would come from the quantity information but not its quality. Controllers would “only” need to deal with voluminous data, to correlate the relevant parameters and to make them correspond to a known category of data. They would never need to make judgements about the quality and accuracy of the information. The controller task would rely on specific “reasoning modes” to filter, organise and categorise in order to simplify the complicated situation. This type of processing requires “computational” strength and very little sensitivity of judgement.

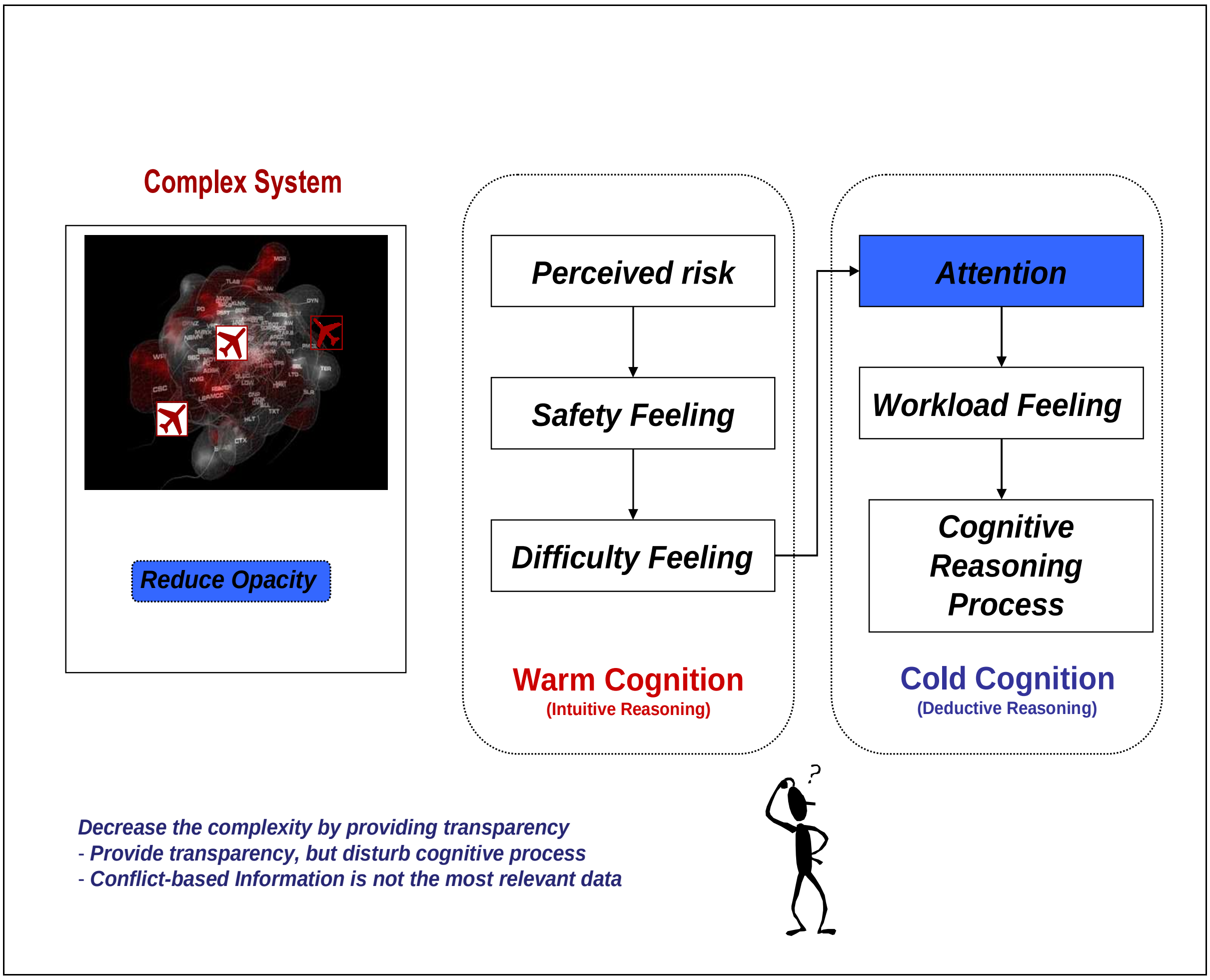
(191) However, uncertainty and complexity do exist within the current ATM environment and therefore the controller cannot rely only on “reasoning modes” to sustain his decision making. ERASMUS presumes that there is a “pre-decisive” process: before turning to cognitive reasoning, the controller first tries to obtain an intuitive sense of the current traffic situation - to “get a feel” for the situation. He or she observes the current state of the situation; it is this first “view” that will determine the controller’s future mental picture of the situation. In others words, the controller’s does not immediately focus on specific pre-identified parameters, but rather considers the situation on a more global level.

(192) It is at this stage, from this initial “situational assessment”, the controller will form an opinion about the perceived risk, a sense of the associated level of safety, and a sense of the associated task difficulty (see Fig. 28). The controller’s subsequent cognitive activities and decisions will be influenced by the results of this orientation. Thus, before drawing conclusions on specific conditions and situations (i.e. "reasoning register"), the controller must first form a basis upon which he or she can predict outcomes (i.e., "judgement register"). It is only then that the controller focuses on specific parameters in assessing the perceived risk.

(193) In others terms, the cognitive activity could be considered a post-processing of the perceptive task. This “pre-decisive” process is mainly the result of perceptive mechanisms and intuition, while the cognitive activity and strategies are determined by emotional, affective and psychological processes. Thus, the assessments of safety, perceived risk, and perceived difficulty all influence the controllers’ cognitive choices. The controller’s evaluation of the traffic situation is subjective first and objective second. Furthermore, resource management has priority over traffic management because it represents a safety condition. The controller is obliged to find a compromise between resource costs and efficiency. In fact, an acceptable solution is chosen based upon this internal context (i.e., intentions, the state of resources etc) and the external one. This implies that an automated system can never be synchronised with human strategies because it is not able to incorporate all of the necessary resource management features.

(194) Since managing risk in the complex ATM system is the main task facing the controller, finding an appropriate solution demands a fundamental change in the problem definition and human factors models. One that appropriately incorporates a previously ignored mechanism - the perceptive, pre-decisive process and its effect on the controller’s cognitive activities and perceived task difficulty. Ignoring this perceptive mechanism and its effects would mean

overlooking an important means of conserving mental resources (see Fig. 27).



Decrease the complexity by providing transparency
- Provide transparency, but disturb cognitive process
- Conflict-based Information is not the most relevant data

Fig 27 – Most ATM concepts provide transparency without taking into account the Perceptive Process ("warm cognition")

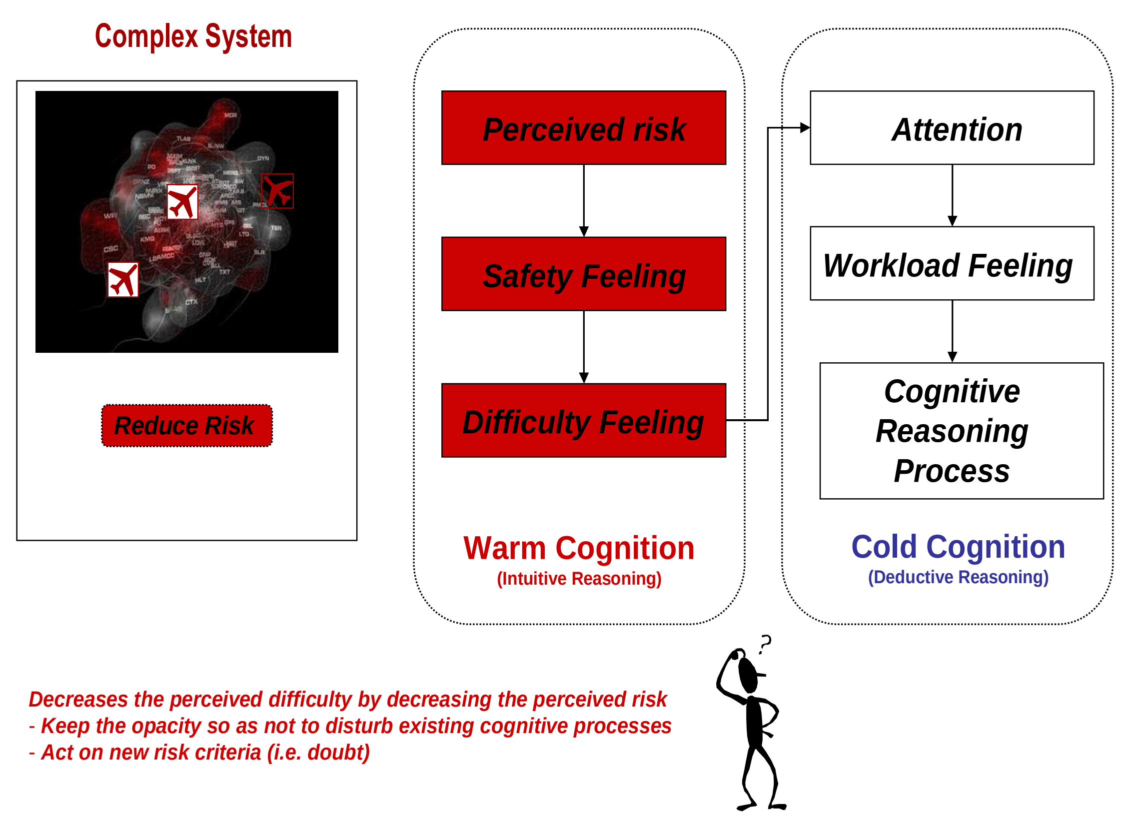


Fig 28 – ERASMUS acts on the controller's perception of risk and their feeling of difficulty

(195) On further consideration, the temptation to provide more transparency to the controller does not seem the best way to help him. In fact, trying to increase system transparency by adding more information actually seems to increase the demands on the controller's cognitive resources.

(196) On the other hand, ERASMUS will act directly on the risk component in order to create a traffic situation that will decrease the levels of perceived risk and difficulty.

A 1.2. Doubt management

(197) Risk is linked to uncertainty which in turn causes the controller to doubt. Managing doubt is a very resource intensive activity – it consumes cognitive resources and represents the one of the main draws on the mental economy.

(198) Because of the uncertainty inherent in the system, the controller's expert judgement is not always able to immediately categorize traffic situations as “conflict” or “no conflict”. Some doubts can remain with regard to any particular perceived conflict. In this case, the controller can let the situation develop in order to refine their assessment and defer making a decision to intervene only when they are certain it is justified. This process does remove doubt, but

monitoring the potential conflict requires an increased level of attention and places additional demands on the controller's cognitive resources. Therefore, the controller can only use this process when there is a sufficient level of mental resources available. This bottleneck represents a main point of the capacity saturation.

(199) In order to manage this doubt when the controller's cognitive resources are close to being depleted, the controller will often classify traffic situations as "conflict" rather then expend precious resources on further monitoring. Consequently, the controller quickly issues an intervention in order to rapidly be unburdened of the problem and able to concentrate on the rest of sector traffic. This strategy allows the controller to conserve resources: they reduce the system complexity by transforming uncertain situations into certain situations and acting accordingly. Not only is the controller able to manage their internal resources to meet the demands of the external situation, they are also able to manage the external situation to meet the limits of their internal resources.

A 1.3. Respecting the controller's activity model

(200) The goal of ERASMUS is to ensure that the requirements of the controller's cognitive model contribute to the principles that, in turn, form the basis of the operational concept. To be feasible and efficient, any step toward the future ATM system must preserve the central role played by controllers, endeavour to form cooperative processes, and be respectful of the delicate processes going on in the controller brain.

(201) The following conditions must be met in order to penetrate the ATM "capacity barrier":

- The controller requires more assistance in managing doubt rather than in conflict detection and resolution.
- The consistency of the controller's cognitive activity cycle has to be maintained. Therefore:
- Any automation and decision-aid tools should avoid disturbing the controller task cycle.
- Automatic functions should be designed to be independent of direct controller activity.
- The controller's expert perceptual assessment forms the basis of the controller's reasoning modes and it must be maintained. This means that any proposed implementation must allow the controller to directly assess the traffic situation.
- Controller autonomy in assessing the traffic situation should be preserved.
- Controller autonomy in managing their internal cognitive resources should be preserved.
- The strategic and tactical choices of controller's should be respected.
- The controller's unique responsibility in any given part of the airspace should be respected.

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ANNEX 2 – OPERATIONAL ENVIRONMENT

(202) ERASMUS will have minimal impact on the working tasks of the pilot. Indeed, from the pilot's perspective, ERASMUS actions will seem like the actions of a competent ATCO - distributing traffic in a way that guarantees the legally required separation between aircraft. In addition, the pilot can interrupt an ERASMUS action at any time, just as they can interrupt those issued by a human ATCO.

(203) Because of the minor adjustments that will be required when potential conflicts are recognized and resolved at a much earlier time, the flight crew should feel they are flying in safer airspace. Dramatic changes by a controller are usually associated with more imminent conflict. Therefore, if only a small change is needed the potential conflict must trivial. ERASMUS will eliminate a significant percentage of potential conflicts which means that there will be fewer traffic calls to the aircrew (e.g., "Traffic at 3 o'clock, Northwest bound at FL 210"), as well as fewer ATCo vectoring calls to other aircraft that are overheard. Both of these situations will reinforce the flight crew's perception of being in a safer airspace.

(204) On the economic side, the potential for ERASMUS to remember the history of each aircraft (e.g., How many times it has been asked to slow down; how many times it has been asked to speed up; where does it stand on making its ETA?) could provide information that could be used to determine which aircraft should be slowed and which sped-up. Given that ERASMUS could hold this data for all the en-route sectors, there is the potential for ERASMUS to use this history and provide speed changes that are optimised for the aircraft's flight path (e.g., avoid being given a speed up command when the previous command was to slow down). As such, ERASMUS could minimize deviations from ETAs and help the air carriers' safe fuel and reduce pollution.

(205) Within the flight deck, one area of design that will require further analysis involves determining what information should be provided to the flight crew that would:

1) make the pilots feel comfortable with the commanded speed change,
2) assist them in monitoring the situation so that they can verify the impact of the speed change on the potential conflict, as well as,
3) help them identify any other unanticipated consequences (e.g., impact of fuel reserves, time at gate, conflicts with other aircraft or weather).

(206) Such information will further enhance airspace safety by allowing more people and technology to verify the consequences of changes to aircraft flight paths.

General	En-route European Core Area
Airspace	Current route network and sector boundaries, above FL 195
A/G exchanges	Data-Link (TP, RTA)
Aircraft	Mixed equipped aircraft (FMS capabilities)
CWP	Radar position, stripless, MTCD
Ground side	Centralised system to manage the ERASMUS actions

General	En-route European Core Area
Airspace	Current route network and sector boundaries, above FL 195
A/G exchanges	Data-Link (TP, RTA)
Aircraft	Mixed equipped aircraft (FMS capabilities)
CWP	Radar position, Electronic striping, STCA
Ground side	Centralised system to manage the ERASMUS actions

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ANNEX 3 – TECHNICAL ISSUES & ENABLERS

A 3.1. Technical Enablers

(207) The 4D trajectory is a corner stone of the ERASMUS concept (Fig. 20): air and ground systems must share this flight information in order to maintain a common, complete and consistent 4D trajectory.

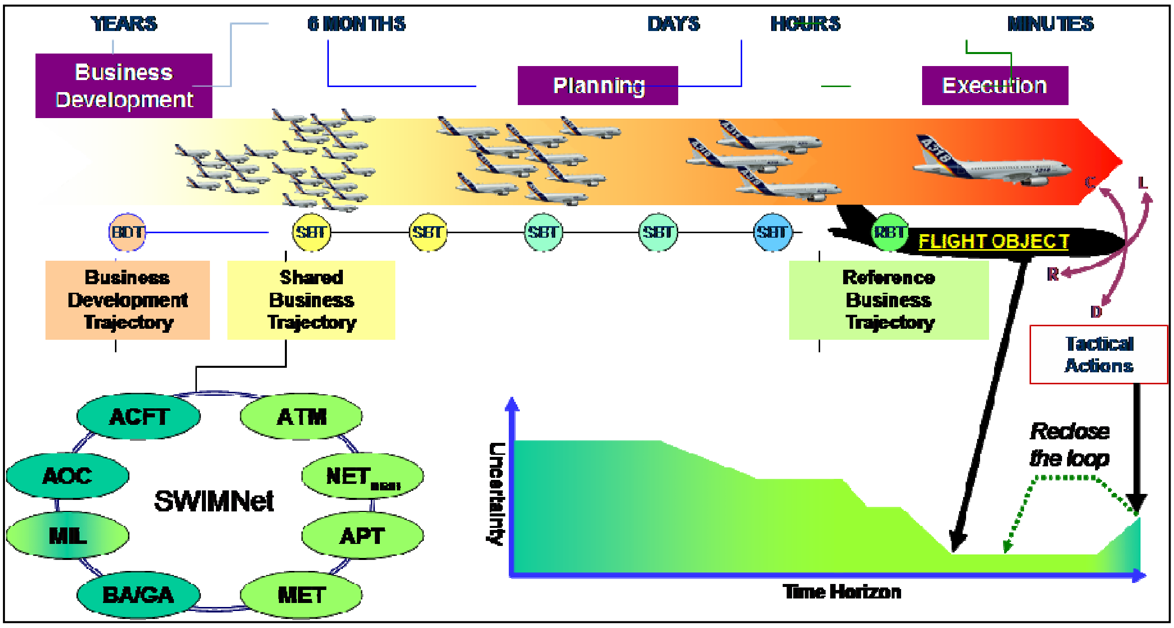


Figure 20 - Continuous Collaborative Refinement of the Layered Planning

(208) The ERASMUS project takes advantage of the 4D trajectory capabilities of the new aircraft:

- The ground system will receive FMS intent data via ADS (periodically or on specified event). Intent data is required in order to:
  - improve the accuracy and the reliability of the ground trajectory prediction, and
  - monitor the implementation of the solution.
- The ground system sends ATC clearances (tactical actions) to aircraft via CPDLC. CPDLC equipment is mandatory to benefit from the ERASMUS service.

(209) The technical architecture and the details of the message exchanges are based on the focused studies of C-ATM (See [18]) conducted by Airbus.

(210) In an ideal world, the aircraft should be equipped with FMS that are capable of managing several RTAs. However, it is expected that airborne systems will first manage one RTA at a time.

(211) ERASMUS actions are mainly based on (but not limited to) the adjustment of the time dimension of 4D trajectories. It will issue standard ATC clearances such as Controlled Time Over (CTO) waypoints.

(212) By contracting part of the trajectory to be flown, the ground system refines the planning and

increases the accuracy and reliability of the next 4D segment.

(213) The responsibilities and authority of both air traffic controllers and pilots remains the same: controllers are responsible for separation assurance and the pilot are responsible for the safety of their aircraft.

(214) En-route sector controllers and pilots may be required to learn new control procedures, complementary to radar control procedures, in order to manage 4D trajectories via 4D contracts. Smooth transitions can be anticipated provided that the 4D traffic is not segregated and provided that this mixed traffic is forecasted over a long period.

(215) A key ERASMUS objective is to allow the airborne advanced guidance systems to fly the aircraft in the most cost-efficient manner, according to operator preferences and air traffic control constraints. A prerequisite for improving air-ground integration is the capability to synchronize the airborne guidance system with the ground-based automation system, especially with regard to aircraft trajectory. The 4-Dimensional (4D) Trajectory Management concept has been identified as a means to achieve air-ground synchronization in future time-based operations. These operations are expected to improve efficiency and capacity on the basis of a paradigm shift away from tactical interventions and towards strategic time-based management (i.e. anticipation rather than reaction).

(216) In the ERASMUS concept, 4D trajectory management is based on the FMS's Required Time of Arrival (RTA) guidance function. RTA guidance is the ability to provide targets for active speed control so as to meet a specified crossing time at a selected waypoint. This guidance concept is also referred to as 4D guidance and time-based guidance. Most modern FMSs are capable of RTA guidance, enabling the aircraft to cross a specified waypoint along the flight plan at a prescribed time within a certain tolerance.

(217) With ERASMUS operations thus relying on 4D Trajectory Management and RTA guidance, the ground automation system assigns the aircraft a crossing time at a specified metering fix. This crossing time is up-linked to the aircraft's FMS, which uses its RTA guidance function to comply with the assigned time. The ground automation system assigns different crossing times to different aircraft with the objective of optimising the overall traffic flow in terms of capacity and overall efficiency.

(218) In terms of air/ground technical enablers, the ERASMUS concept thus requires aircraft be equipped with a RTA guidance function and an air and ground data link function that allows the aircraft to downlink the aircraft flight profiles and allows the controller to transmit crossing time clearances to the pilot.

(219) The project considers that such technical enablers are already available or will be available in the near future:

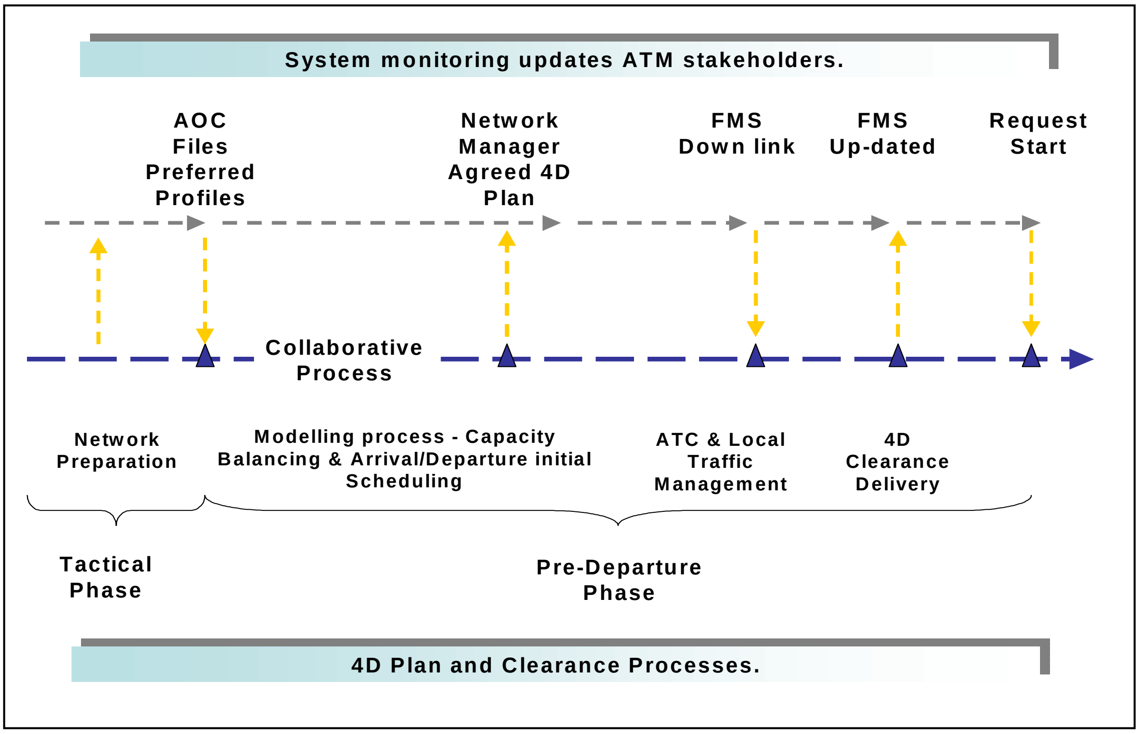
- Automatic Dependent Surveillance-Broadcast (ADS-B) application, as currently defined, enables the transmission of the aircraft trajectory intent data to the ground systems.
- Controller Pilot Data Link Communication (CPDLC) application, as currently defined enables the exchange of clearances and messages between controllers and pilots.
- Most modern FMS are already capable of RTA guidance.

(220) In Europe, ADS-B and CPDLC applications are part of the EUROCONTROL Co-operative ATS through Surveillance and Communication Applications Deployed in ECAC (CASCADE) programme. The objective of this programme is to plan and co-ordinate the implementation of the first set of ADS-B applications and CPDLC services in the 2008-2011 timeframe within the ECAC area. In terms of data link infrastructure, it is considered that the ERASMUS project will rely on the outcomes of the EUROCONTROL CASCADE programme.

(221) Using these three technical enablers, the ERASMUS ground automation system can assign different crossing times to different aircraft with the objective of optimising the overall traffic flow in terms of capacity and overall efficiency. In ERASMUS, the capacity gain is obtained dynamically (i.e. in real-time). As this dynamic increase of capacity is beneficial only when it is exploited to manage more traffic demands, the Air Traffic Flow and Capacity Management (ATFCM) function will have to use this new capacity.

A 3.2. 4D Plan

(222) Significant improvement in ATM services are predicted from the use of 4D information provided by the airline or the aircraft FMS. This includes preferred route planning and continuous adjustment of 4D plans in order to satisfy a Requested Time of Arrival. RTA becomes one of the main objectives of the ATFCM process (Fig. 21) . The expected benefits are: greater predictability and therefore improved safety, reduced holding, improved arrival management and associated reduction in "bottlenecks", and efficient aircraft operation and fleet management.



(223) A 4D plan is a flight profile based on the airspace users profile request and which provides information on: Route and profile, Estimated Off-Block Time, Calculated Take Off Time, Target Time of Arrival information for sector entries, initial and final approach fixes, and Expected On Stand Time. It expresses the agreement between the network manager and airline operations centre as to how the flight should proceed and reflects the capacity and demand situation for airport and airspace resources.

(224) The 4D plan is opened to renegotiation between AOC, MSP function and or ATC through a co-ordination with the central ATFCM unit. However, the central ATFCM unit may delegate implementation of a dynamic (real-time) ATFCM action to the local traffic manager or ATC.

(225) 4D plan quality depends on shared and up-to-date data from each involved party provided through the network operations plan.

A 3.3. Data-Link Communications

(226) It is expected that whenever feasible, advance instructions will be provided to pilots by local traffic managers for traffic synchronisation or traffic organisation and by sector or tower controllers for plan amendments or separation management purposes.

(227) The communications that are expected to be used include:

- ATC Communications Management Service : ACM;
- Departure Clearance Service: DCL;
- ATC Clearance and Information Service: ACL;
- Downstream Clearances Service: DSC;
- Flight Plan Consistency Service (4D): FLIPCY 4D;
- Common Trajectory Coordination: COTRAC;
- System Access Parameters Service: SAP.

(228) 4D plans can be provided or amended via the above services or by ADS-B (to be defined) data link services.

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