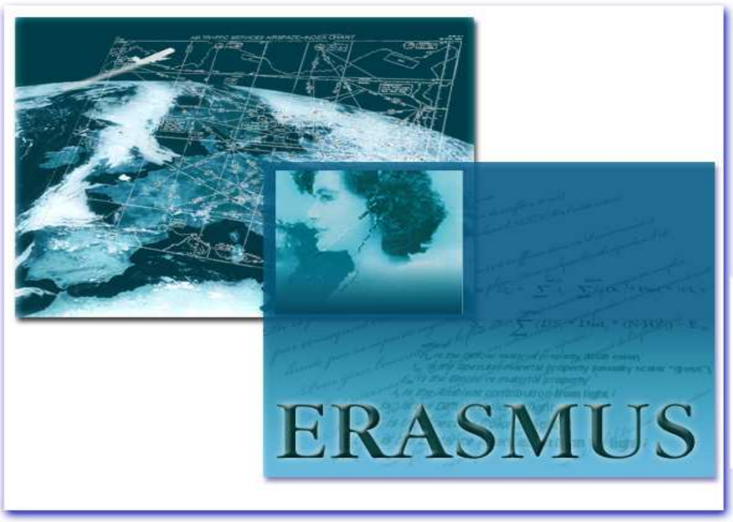
PRIORITY 4 - AERONAUTICS AND SPACE



ERASMUS - VALIDATION PLAN

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Document approval

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2.2	28 July 2008	Released version	

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Contents

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Executive summary

(1) The Validation defines a strategy and a plan to conduct investigations in order to validate the hypotheses, to provide strong arguments and performance assessment, using a range of experimental techniques (modelling, simulation, clinical…).

(2) It will be based on a rigorous process aiming at fixing a validation framework and will be based on the E-OCVM methodology which gives guidelines in order to structure the design and validation process according to precise lifecycle view. Mainly, it provides elements to plan and structure the validation (the stepped evaluation view) and to integrate experimental information into cases (the case view developing safety cases, human factors cases, technical cases, business cases…).

(3) Performance assessment experiments will address the stakeholders' needs and expectations. The high level expectations of airspace users are to be able to conduct their operations with minimum restrictions, maximum flexibility and cost-effectiveness, whilst minimising the environmental impact. The validation activity will perform performance assessments experiments and studies to provide strong arguments of evidence (safety, efficiency,…) and to assess the most critical operational concept elements with respect to stakeholders' expectations.

(4) Key Performance Areas (KPA) are aligned with the SESAR description. For each KPA, target setting are identified to define achievable performance levels. The associated KPI (Key Performance Indicators) are identified to fulfil the KPA assessment.

(5) A set of arguments (safety, efficiency, technical feasibility) are proposed in order to give clear direction to the stakeholders and decision-makers.

(6) The scope of the ERASMUS performance assessment experiments is located on a local ECAC-wide nature representing a high-complexity en-route area.

(7) The involved partners are confident that the present plan adequately explains the structure of their work and provides a useful starting point to perform the experiments. This document also provides sufficient information to explain which results can be achieved within the specified timeframe.

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1 Introduction

(8) This ERASMUS VALIDATION PLAN document is a document for both ERASMUS Management and all other project stakeholders. It defines a strategy and plan to conduct modelling and simulations activities in order to achieve assessment results regarding the performance of the SESAR concept and to develop arguments for the stakeholders and decision-makers.

(9) This document defines the ERASMUS Operational Concept Validation activities on the Programme Level. This includes the validation of the necessary Enablers. It will define the necessary projects to achieve the ERASMUS validation objectives and the approach to consolidate the project's findings on the programme level.

(10) The Validation Plan will be used to define and support the experiments to be conducted in the WP4.3 and WP1.3. The experiments and experimental conditions are determined by the KPA and arguments, and are worked in a more detail by applying the E-OCVM methodology.

(11) This document represents the ERASMUS project delivery **D 4.1 version 2.0** part of the WP4.1 as defined in [2].

1.1 Document Structure

(12) This documents is structured on 11 main chapters:

- Chapter 1 introduces the document.
- Chapter 2 provides a general introduction into the ERASMUS Programme and the scope of this Validation Plan Document.
- Chapter 3 presents the validation methodology applied by the ERASMUS Programme.
- Chapter 4 positions the ERASMUS validation activities into the European ATM R&D context.
- Chapter 5 quantifies the ATM needs to be addressed, namely the key performance areas, SESAR targets, and the key performance indicators.
- Chapter 6 provides an overview over the ERASMUS Concept and identifies its expected benefits.
- Chapter 7 identifies the ERASMUS Programme Influences and Objectives, namely its objectives, stakeholders, dependencies and other influences.
- Chapter 8 states the ERASMUS Validation Expectations and Objectives, namely the required supporting cases, validation objectives and initial validation needs.
- Chapter 9 sets the ERASMUS Validation Strategy and proposes a set projects to implement that strategy.
- Chapter 10 provides management information on the resources, the validation milestones and deliverables, the identified risks and mitigation.
- Finally chapter 11 presents in annex a review of the existing validation programmes and results.

1.2 Document evolution & approval

(13) Revisions to the validation plan will be done through periodic reviews performed in close cooperation with project partners. A group in charge of updating the validation content has been created and has also been tasked with collecting and integrating input from the different working groups and Work Projects. Next validation versions are planned for Dec'2007 (version 2) and Aug'2008 (version 3).

(14) 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 and pilots 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.

(15) The graph below represents this iterative process:

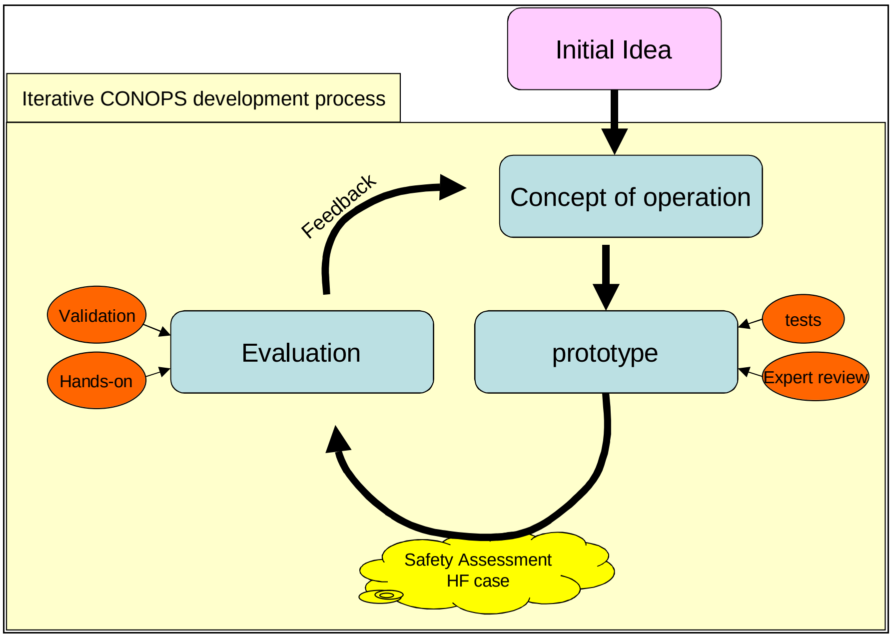

Figure 1: Operational concept iterative improvement process.

1.3 Reference materials

(16) The documents referenced in this document include:

[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] ERASMUS Concept of Operation – D2.2.1 (ERASMUS - WP22 - CONCEPT-OF-OPERATIONS - V1.4, 2007)

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

[7] 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.

[8] 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.

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

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

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[19] C-ATM Focused Studies – 4D Trajectory Exchange, Version 1.5, 13 March 2006.

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

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[24] Complexité et conscience de la situation, aides au contrôle de processus dynamique, d. Javaux, v De Keyser, iin Amalberti (ed.), Briefings, IFSA - Dédales, Paris

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[26] 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.

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

[28] 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

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1.4 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 Operation Center
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
DTI - SDER	Direction de la Technique et de l'Innovation – Service des Etudes et de la Recherche (formally CENA)
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

Case	A coherently structured set of evidence to support the belief that a system will operate within the desired bounds. This definition is a generalisation of the definition of a safety case in UK MoD JSP 430[1]. In a generalised case, the desired bounds may be any combination of cost, performance, safety, reputation, or any other aspect influencing the decision to operate the system. The case is something produced. An organisation can 'hold a safety case'. The case is distinct from the process that generated it, though a robust case clearly needs traceable evidence of how it was created, and where its information and assertions come from.
System	An inter-connected set of people, technology and processes that performs a set of services. The key point is that any practical system includes people, who are critical contributors to its performance, cost, failure modes and recovery modes. Many of the issues about 'whether to do HF' vanish once this is truth, together with the associated risks and benefits, is fully understood. They are replaced by issues about 'how to do HF, and to what extent'.
Operational concept	A description of how a set of services could be provided, i.e. the abstract precursor that when implemented becomes embodied in a system. E-OCVM already recognises the continuity between the abstract precursor and the operational system, so E-OCVM is really about much more than just the operational concept. The message of E-OCVM is that the validation process should start when the concept is being designed, not be added on after the system (in the sense above) has been designed. The key point is that E-OCVM does not just validate the concept; it also validates the system that implements the concept.
Contributory disciplines	HF, Safety, Business, Environment, Technology, etc., all provide different perspectives on the system (and the process of creating and validating it) but they are not orthogonal, and certainly not non-overlapping.

Table 2: Definitions

[1] A Safety Case is a documented body of evidence that provides a demonstrable and valid argument that the system or equipment is tolerably safe for use: within a defined envelope, throughout the proposed life of the equipment.

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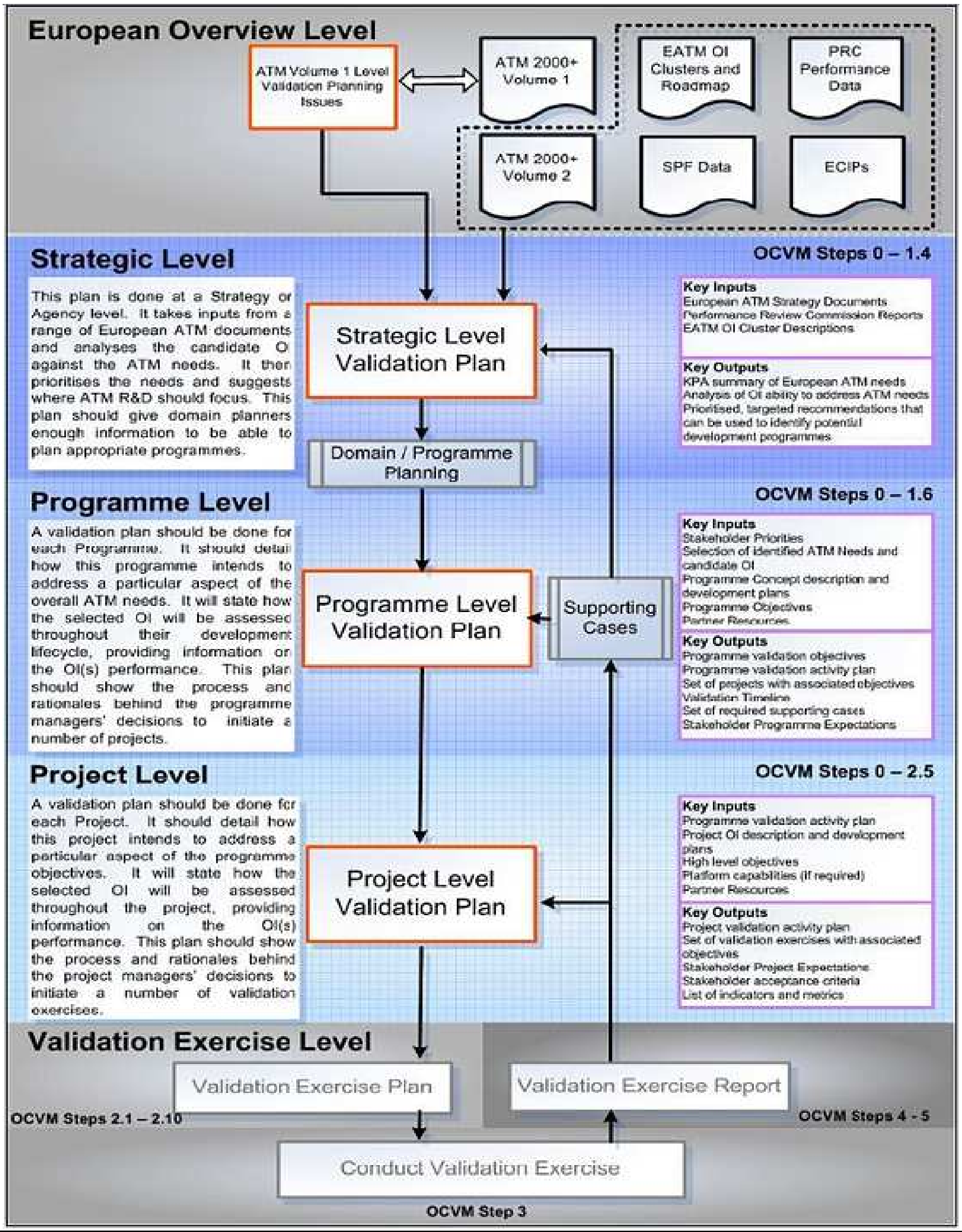
2 Validation methodology

(17) ERASMUS is following the E-OCVM approach for Validation. The concept proposes several changes to the actual picture of ATM: some technological changes, some changes of responsibilities, some changes in traffic delivery, and some changes in working methods. The validation activity should cover all these aspects and relate them to the project goals.

(18) The schema below shows the general validation planning approach:



(19) The E-OCVM Lifecycle Model depicted below is used as the planning framework for this Programme Level Validation Plan:

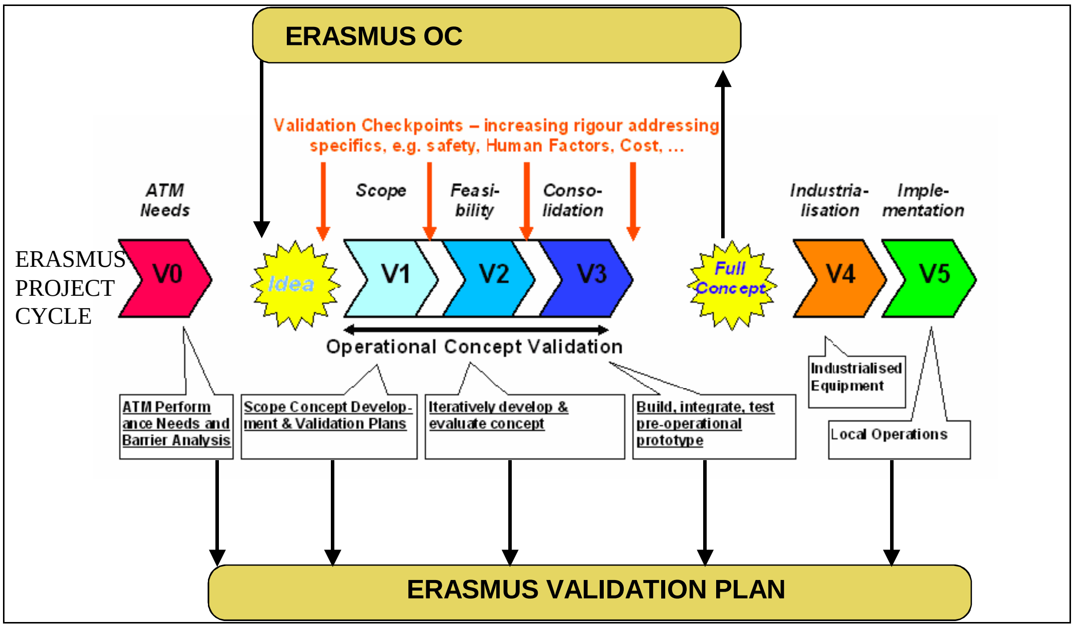


Figure 1: ERASMUS Development

(20) The validation process is connected to the others parts of the project lifecycle. Three different processes are articulated:

- **The assumptions matrix:** the assumptions are worded to improve the understanding, the analysis of the problem and its solutions. It represents the heart of the validation process because the assumptions define the content of this process and this content determines the required validation methods and supports.
- **The validation strategy and supports:** it concerns the definition of the refutability conditions of the assumptions which sustain the operational concept. The relevant variables (which are involved in the high-level concept) are isolated and made operational (i.e. concrete, observable) in order to assess the concept. The other elements or "parasitical variables" which could influence the results have to be identified in order to be better controlled.
- **The operational concept definition and development (design):** the design choices directly influence the methods and tools which have to be selected to conduct the validation.

(21) The global structure of the ERASMUS validation approach is illustrated in the figure below.

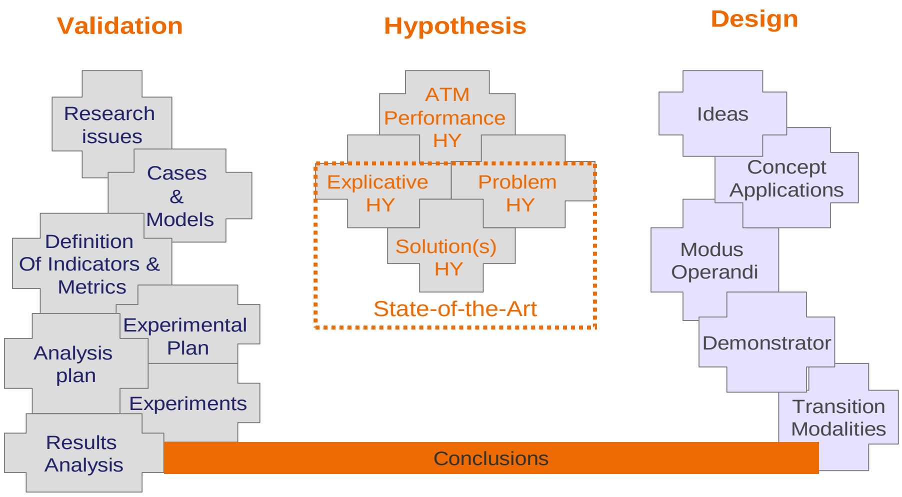


Figure 2: Global view of the ERASMUS validation process

(22) Seven main steps are identified during the global validation lifecycle:

- Step 1: Definition of the assumptions
- Step 2: Identification of the research questions
- Step 3: Definition of the indicators and metrics
- Step 4: Production of the experimental plan
- Step 5: Elaboration of the analysis plan
- Step 6: Conduct of experiments
- Step 7 - Results and conclusions

2.1 Step 1: Definition of the assumptions

(23) Four different categories of assumptions are successively defined:

1. **ATM Performance Assumptions**: identification, dimensioning and formulation of ATM system objectives according to a set of specific criteria (in terms of capacity, safety, quality, punctuality, …)

   Ex.: Double the current sector capacity

2. **Problem Assumptions**: they are directly linked to the performance assumptions because a problem only exists in reference to an identified objective. They sum up the reasons why it is not currently possible to fulfil the different performance objectives. They are assumptions on facts.

   Ex.: The Radar Controller is not able to simultaneously deal with more than 25 flights. Thus, this limit can be considered as the main system bottleneck.

3. **Explicative Assumptions**: they make the link between the performance objectives and the problem statements. In this case, the issue is to know why specific problems exist. They detail the causes and the explicative fundaments. They are assumptions on mechanisms. Let us note that it is important to distinguish the facts description of the problems (= problem assumptions) and the explanations of them (= explicative assumptions). Their levels are different. For example, it is not the same thing to say “the traffic is not sufficiently organised” and to give the reason(s) why. In the

same idea, a similar stated problem could refer to different and contradictory explanations. And this will change the solution choice, because a solution does not depend on the state, but on the causes of the problem. Furthermore, that changes the definition of indicators, the determination of research questions and the results interpretation. If some results are not really exploitable, it is often because the problem assumptions are not made explicit. So, it is only possible to state a correlation, but not to know if it is significant or not, because the explicative variables are not so mastered neither operational.

Ex.: The human mental resources are limited and it is the doubt management that mainly consumes them, notably when the risk of conflict/no conflict is not directly perceived as a certain one.

4. **Solution Assumptions**: they have to be deduced from the previous set of assumptions. They concern the way to fulfil the objectives regarding the specific problem and its explanations. Thus, they precise the choices in terms of response to the addressed problem. They are assumptions on solutions.

   Ex.: Add some technical aids, which are able to make clearer the perceived risk of conflict, in order to reduce the resources consuming of the radar controller in the doubt management.

(24) Consequently, it is both important to formulate the assumptions and to identify their relationships. On this basis, the role of the validation is to confirm or infirm the content of those assumptions and their links.

(25) Let us recall that the definition of assumptions is sustained by a state-of the art[2].

(26) At first, assumptions are listed in a specific support: the assumptions matrix (cf. Annex 1).

2.2 Step 2: Identification of the research questions

(27) In confronting the assumptions matrix to the initial ideas (defining the operational concept at a high-level), specific issues are identified. They put the light on what we have to focus the attention in terms of research questioning. The formulation of the research questions consists in transform assumptions in concrete and delimitated questions.

(28) The means of this transformation is the use of analysis grids: the available models of ATM and/or a case-based approach. They help to better understand the relationships between the ATM components. It is essential because the ATM is a complex system in which the links are not so visible and rarely one-to-one. The issue is: when you act on a specific component, what are you going to impact, directly or not? What are the “side effects” of a design choice? How is it propagated in the system? Let us take an example: the implementation of an automatic tool may impact the reasoning modes, the strategies to cope with the complexity, probably the responsibility feeling, the safety feeling (…) of the controller. Thus, the important fact is not only to know that there is an impact, but also to identify the nature and the conditions of this impact. Recall that the system balance requirement is an essential validation criterion.

(29) Moreover, this work is an input to define the first versions of the operational concept and its modus operandi description.

2.3 Step 3: Definition of the indicators and metrics

(30) The refinement of the research questions allows determining the indicators that correspond to the variables and criteria which are concerned by the validation. Let us recall that the change from KPA to

[2] For more details on the state of the art content and issues, refer to the D2.1.

KPI is not direct and systematic. It requires the reference to the assumptions and the research questions. Moreover, they depend on the project maturity (for example, it does not seem currently relevant and possible to investigate the number of accidents to estimate the safety KPA). In addition, some indicators concerning not only the performance area but the consistency and the robustness of the concept too, are investigated. The choice of each indicator has to be argued regarding the process that it attempts to reflect. Actually, some observable indicators can be too partial or may refer to multiple processes or even be “false friends” (for example, in the case of the cooperation, it is not correct to deduce that a lot of verbal communication between two operators means an high-level of cooperation: it may refer to the opposite fact). Thus, a particular attention has to be put on the indicators selection. The indicators are listed and explained in the experimental plan.

(31) At this step, the data to be measured, in order to access to those indicators, are defined too (= metrics). On this basis, the set of the adapted methods is chosen (for example, determine the way to collect objective and subjective data, decide the type of interviews, determine the content of the observation grids during simulations and so on). The metrics are detailed in the analysis plan.

(32) Thus, the experimental plan and the analysis plan of results are simultaneously drafted. They present and argue all the relevant means and tools to use.

2.4 Step 4: Production of the experimental plan

(33) The previous steps provide the elements to determine the characteristics, the needs and the level of development of the experimental environment. This information is regrouped in the experimental plan. An ideal experimental environment does not exist in itself: it depends on the validation objectives and on the data to be collected. Demonstrator/simulators have to be designed regarding this principle.

(34) The global experimental plan regroups the sub-experimental plans which are elaborated for each experiments (several experiments or pre-experiments could be required). It details:

- The concrete experimental strategy,
- The experimental scope: means (tools, techniques, platforms, …); ATM environment (airspace used; chosen sector); organisation (number of working positions, type of team, …); duration and number of exercises; scenarios, training conditions and requirements,
- The experimental planning and management: staff resources and skills; responsibilities identification; partnership; tasks listing and planning; preparation meetings; specific milestones; risks identification and management modes.

2.5 Step 5: Elaboration of the analysis plan

(35) The global analysis plan regroups the sub-analysis plans which are elaborated for each experiments. It aims at giving the guide according to the data will be processed and analysed in order to confirm/infirm the concept assumptions. Thus, it details:

- The list and definition of the different metrics,
- The means (and their arguments) that will be used to process the data, to transform them into results and to support their analysis (statistical tools; encoding data modes; content analysis software, …),
- The conditions and levels which will allow to determine the confirmation of each assumptions (for example in mentioning the acceptable rate, the potential impact of the parasite variables or the statistical significance threshold). Those criteria are explained (why are they chosen?),
- The theoretical models which could be used to interpret the results (for example what kind of complexity models? which type of cognitive approach? …),

- Information on the analysis process organisation: the quantitative and qualitative resources (expertise domains) that will be involved in the analysis of results; the length of the analysis; the responsibilities.

2.6 Step 6: Conduct of experiments

(36) Before beginning the conduct of the experiments a preliminary phase is carried out in order to test the specified experimental platform and the different supports (for the data collection, the validation team tasks sharing, …). The ERASMUS experiments will take place in an operational centre of control. Thus, a pre-experiment visit is required to make everything compliant with the experiments requirements. Just before to begin the experiments, the responsible of the experimental sessions achieve a final briefing with the validation team.

(37) In a second stage, the experiments really begin following those steps:

- Presentation of the experiments to the controllers who will participate (objectives; the course of operations, the specific expectations from the participants; validation team roles; controllers questions),
- Training session (if it is required by the experimental protocol),
- Precise and clear announcement of the orders concerning the experimental task,
- Starting up of the experimental session and data collection process (data recording by an automated system; observations; operators verbalisations collection; interviews; questionnaires; video recording; …),
- A debriefing ends the session with the involved controllers (to collect their opinions on the experimental process, to answer to their specific questions and to describe the perspectives of the project and the process to inform them of the results).

2.7 Step 7 - Results and conclusions

(38) At the end of the experimental process, the collected raw data are formalised, analysed and interpreted according to the analysis plan. The confirmed/infirmed assumptions are clearly listed. When it is possible, some explanations about those results have to be presented. If it is not the case, the new research questions have to be proposed. The level of expectation, regarding the initial performance assumptions, is discussed. Simultaneously, the transition issues are developed.

(39) Lastly, the conclusions of the validation are worded. The nature of those conclusions varies according to each lines of the project (validation strategy, assumptions and operational concept definition):

- **Validation strategy**: the conclusions have to provide improvements in terms of assessment or revision about the rigour of the methods and about the relevancy of the tools which have been chosen. That provides a rating about the quality of results.
- **Assumptions**: the conclusions provide new elements to enrich the state-of-the-art in the ATM domain. Whatever the results of the project are (which means confirmation or not of the specific hypothesis), it offers an added knowledge for the future projects or concepts. That constitutes the basis of a “learning process” which is addressed to the ATM community.
- **Operational concept definition**: the conclusions focus on recommendations about the design choices relevancy. They are related to the conditions of transition both at technical and human levels. They provide information on the probable feasibility, viability or acceptability of the operational concept.

(40) All those elements (results, new research questions, transition issues and conclusions) are regrouped in a global and complete report. Others versions could be worded to be adapted to the different stakeholders and decision makers expectations (more or less light, insisting on targeted points, …). This is the final step of dissemination which begins.

3 Programme place in European research and development strategy

3.1 ATM needs being addressed

(41) ERASMUS has decided to focus on the management of traffic complexity, which is one of the ATM complexity components, in the future ATM environment, making the assumption that a part of complexity management should be transferred to automation in order to improve operational performances (capacity and efficiency).

(42) The objective of the ERASMUS project is twofold:

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

(43) The ERASMUS project identifies and deals with two main problems:

- Problem 1: The impact of the overall ATM system complexity on the controller,
- Problem 2: The Human – Machine interaction (ensuring that the impact on pilots is acceptable and that pilot interaction with enabling technology is operationally viable).

(44) These problems are addressed by exploring the following solutions:

- Solution 1: Acting on the traffic complexity delivered to the controller,
- Solution 2: Acting on the level of information exchanged between the human and the machine and on the level of autonomy / dependency of the agents.

3.2 Operational Improvements being developed

3.2.1 Overview

ERASMUS Applications	Current Level of Maturity	Target Level of Maturity	Initial Implementation	Full Implementation
Strategic de-conflicting	Pre-V2	V3		
Separation Management	(initial "proof of concept", prototypes)	(concept integration, pre-ops simulations)		

3.2.2 Rationale

(45) In order to develop the different services provided by the ERASMUS concept, the project proposes two applications :

- Strategic de-conflicting,
- Separation management.

(46) The Strategic De-conflicting which will provide:

- Higher accuracy for Trajectory Prediction and potential conflict occurrences based on high-precision FMS TP Capabilities;
- Trajectory modification where the 4D Business trajectory is modified by minor speed adjustments (subliminal action).

(47) Concerning the separation management function, the ERASMUS project shall address the operational flexibility of the Strategic De-conflicting and its capability to be adapted to existing separation management process and controller's tools and working methods as well as its compatibility with airborne equipment and procedures. The ERASMUS concept is calling TC-SA (Trajectory Control by minor Speed Adjustment) separation mode in the SESAR concept and documents. The ERASMUS elements are identified in the transition phase corresponding to the 2020 horizon (Intermediary Period 2).

(48) In consequence, it is proposed to identify the performance improvement of the ERASMUS Server within a 2007 baseline ATM environment and a defined SESAR 2020 ATM environment.

(49) Application 1 – The Strategic De-conflicting: the machine will automatically resolve conflicts by minor alterations of the speeds or rate of climb with no human being intervention.

(50) In SESAR, the Strategic de-conflicting function aims at adjusting the 4D Business Trajectory in order to optimise the separation management: the objective is to reduce the controller workload associated with routine monitoring and conflict detection and to moderate the interventions of ATC in changing flight profiles to resolve potential conflicts.

(51) To adjust the 4D Business Trajectory, two enablers are required:

- the trajectory prediction,
- the trajectory modification.

(52) In ERASMUS, the trajectory modification conforms to the SESAR definition, with the particularity that the 4D Business trajectory is modified by minor speed adjustments (subliminal action).

(53) Considering that a slight variation in an aircraft speed or climb rate, imperceptible for the controller, can be sufficient to prevent a latent conflict (15 minutes in advance a difference of some 2%, less than 10 knots, in the speeds of both aircrafts would change a "conflict" into a "non conflict"). Such accuracies are far out of reach of the controller (perception) sensorial picking and mental computing. Therefore, the machine reasoning can solve conflict by minor alterations of the vertical/horizontal speeds or rate of climb/descent for a given aircraft, so that it does not significantly modify the flight plan as they are fuzzily known by the controllers (human-like reasoning). The computer will have a "free zone" of autonomous initiative at the border of the "private zone" of responsibility of the controllers.

(54) Such actions can be qualified as subliminal, since they are not directly perceivable by the controllers and not conflicting with their own action and responsibility. It can be expected that a very large number of conflicts could therefore be eradicated.

(55) This is the most powerful opportunity offered by the air/ground data-link for transforming the current "open loop" into a "closed loop" ATC as well for the computer-to-computer clearances delivery.

(56) In summary, since it is not possible to free the controllers from the fuzziness of their perceived environment, the idea is to make profit of this fuzziness to allow the computer to navigate inside it, not for solving the conflict but for dissolving the conflict. The prediction is not used to inform the controller about conflicts but is exploited in an air/ground closed-loop without interferences with the operator activity.

(57) It must be clearly recognised that neither the responsibility nor the freedom of both the controller and the pilot will be limited by the subliminal control. At any time, the controller remains able to issue any

classical clearances and the pilot remains able to modify the flight plan after agreement with the controller.

(58) This application should be located at a strategic level in the Multi Sector Planning (MSP) function, which current envisaged role aims at “de-conflicting” the conflicting traffic. This de-conflicting by dissolving the conflict is transparent as regards sector entity. The difference between the current MSP function and the subliminal application is the fact that the subliminal mechanism performes minor adjustment in full automated closed loop and not perceivable by the controller of the sector entity. It aims at resolving the barriers encounter in the current MSP approach.

(59) Application 2: The Separation Management: to address the operational flexibility of the ERASMUS Server and their ability to be adapted to existing separation management process and controller’s tools and working methods.

(60) ERASMUS will address two scenarios (defined by SESAR) regards to the separation management function:

- Baseline scenario (current ATC system)
    - Trajectory Prediction (with limited-accuracy)
    - CTA/CTO management (one constraint - FMS)
    - Strip-less environment
    - Safety nets (ACAS, STCA)
- SESAR 2020 scenario aiming at demonstrating the feasibility and efficiency of the ERASMUS in 2020. To define this 2020 scenario we need to take into account the SESAR 2020 ATM Capability Level, e.g. the ATM capability level 3. ATM capability level 3 corresponds to :
    - 4D Trajectory sharing A/G (with high-accuracy, high frequency D/L);
    - D/L capabilities;
    - CTA/CTO management (multiple constraints - FMS) ;
    - Cooperative separation functions (action delegation);
    - Conflict detection and resolutions applications;
    - Conformance monitoring;
    - Safety nets of potential future systems (ACAS, STCA);
    - ATCo side operational requirements and behaviour;
    - Pilot side operational requirements and behaviour.

(61) Variable parameters will be:

- Fleet equipment (100%, 60%, 30%);
- FMS TP/RTA accuracy (0.1 Nm, 0.3 Nm, 1 Nm, 2 Nm);
- Reliability of information (uncertainty model);
- Traffic increase scenario (+20%, + 50%, +100%).

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4 PERFORMANCE FRAMEWORK

4.1 Key Performance Areas, definitions and expectations

(62) ERAMUS is fully aligned with the SESAR Performance Framework that was produced by SESAR Task 2.1.2, as a component of the Strategic Objectives Definition to be referred to by SESAR Deliverable 2. In turn this framework relies heavily on previous developments such as the ICAO Performance Based Transition Guidelines, the Performance Review Commission reports and guidelines, etc.

(63) The performance framework aims at structuring the performance problems in terms of expectations, objectives, targets and indicator, the latter being expressed as quantifiable values.

(64) In the context of Performance Assessments based on Fast Time Simulations, indicator values will be used to assess the possibility of meeting the stated targets using the selected operational concepts or concept elements. In turn these indicator values will be computed using formulas and metrics, the latter being direct outputs of the simulators themselves.

(65) This section describes the achievable SESAR expectations with respect to KPAs, as well as their definitions of the ones that will be addressed in ERASMUS.

(66) Reference document for SESAR T2.1.2 task output is its task deliverable prepared for SESAR Deliverable 2, as *Strategic Objectives Definition*, document number DLT-0607-212-01-02, dated 17th November 2006 [Ref. 12].

4.2 SESAR Targets

(67) The demand for air transport continues to grow (5% traffic increase/year). In order to cope with this challenging traffic demand the European Commission launched the SESAR project. SESAR is expected to deliver a future Air Traffic Management System for 2020 which can enable-up a 3-fold increase in air traffic movements whilst reducing delays, improve the safety by a factor 10, enable a 10% reduction in the effects aircraft have on environment and provide ATM services at a cost which is at least 50% less.

(68) ERASMUS is expected to provide some targets contribution to SESAR in the en-route sector productivity area.

(69) The Performance Review Report (PRR 2005) of the EUROCONTROL Performance Review Commission (PRC) analyses the performance of the European Air Traffic Management System in 2005 under a number of Key Performance Areas (KPA): Safety, Delays, Cost-Effectiveness and Flight Efficiency.

(70) Following this approach and the E-OCVM[3] recommendations, the ERASMUS project selected a subset of KPA within the current performance framework proposed by PRC, SRC or ICAO[4].

(71) It's worth noting that SESAR has revised this performance framework[5] and possible adjustment might be envisaged during the project if necessary.

[3] E-OCVM: European Operational Concept Validation Methodology

[4] Refer to ICAO OCD: Global ATM Operational Concept Document

[5] Refer to SESAR Deliverable 1, Air Transport Framework, The Current Situation

(72) ERASMUS is focusing mainly on the capacity issue while maintaining and possibly improving the current level of safety. The capacity will be gained indirectly by improving the controllers' productivity for En Route sectors: the cost effectiveness study is not driven by cost reduction but aims at finding capacity gain. Minor adjustments of speed should improve the flight efficiency by preventing controllers' actions such as vectoring.

(73) Impacts on other performance areas will be assessed during the validation process of the project.

(74) The table below lists the KPAs as identified by the PRC and their correspondence in the ICAO/SESAR framework (Columns "KPA"). The "ERASMUS Target" columns indicate which KPAs are "for the ERASMUS project and provide comments on the objectives of ERASMUS in each performance area.

Key Performance Area		**ERASMUS Target**	
SESAR proposed	**ICAO proposed**	**Selected KPA**	**KPA Objective**
Safety		Yes	Maintain or improve current level.
National security and Defence requirements	Security	No	Assess security issues related to the datalink enabler
Delay, Capacity, Airport Capacity	Capacity	Yes	Improve en route capacity: +20% in 2015 (current airborne equipment) +70% in 2020 (enhanced FMS functions utilization) Maintain and possibly improve the amount of en route delay. Airport and Approach capacity/delay not considered.
Cost Effectiveness		Yes	Improve controller's productivity in en route sectors
Flight efficiency	Efficiency	Yes	Prevent vectoring control actions by minor speed adjustments
Environment		Yes	Assess environmental impacts during Human-in-the loop experimentations
Flexibility		No	N/A
Access	Access and Equity	No	N/A
Uniformity, Common Standards	Global interoperability	No	N/A
	Participation by ATM Community	No	N/A
Punctuality and Predictability	Predictability	Yes	Investigate enhancement of ground and air trajectory prediction

Table 1.1 : Acronyms and abbreviations

4.3 Key Performance Indicators, selection and definition

(75) This part presents the SESAR KPI addressed by the ERAMUS validation strategy.

- **Cost-effectiveness:** This is a major area of expected operational improvement to be addressed for performance of individual as well as overall operations of flows of flights, of airport operations and of operations within specific geographical areas. Investment cost can not be addressed. Flight operational costs can be addressed only as far as they are related to performance aspects and not to internal company policies and impact on Airlines' operational deployment of their fleet.
- **Capacity**: This is a major area of expected operational improvement. This KPA shall be addressed through measuring throughput, in some cases by measuring workload and delays.
- **Efficiency:** The same as for cost-effectiveness, but this time related to flight performance, airport performance and ANSP performance aspects. Efficiency is assessed through measuring delays, workload and flight path efficiency.
- **Flexibility:** Evidently a strong requirement of airspace users that has to be reflected by interoperability of planning and reactivity on delays and incidental disruptions. It is not evident where and how to assess performance aspects.
- **Predictability:** All concept elements related to use of management, planning and intent information can be assessed on their performance behaviour with respect to predictability. In general, the KPIs, associated with Target Time, Managed Time, Planned Time and Actual Time, are addressing time references used to measure potential performance improvements of advanced concepts.
- **Safety:** This area is an important area of performance assessment due to the critical role of this KPA in the success of the SESAR concept. However, the experiments to be performed in order to assess safety in an appropriate and confidence providing way is very specific, labour intensive and complex. Therefore, this KPA can be addressed only in a very limited and restrictive way, giving in some cases for some concept elements of interest partially significant results. Essentially, these results are focusing on propensity and resilience, measured by intermediate distances and complexity of air traffic situations.
- **Security:** The high level view on how to measure and assess performance aspects within the scope and context of actual performance assessment experiments is composed of four steps. The first is an analysis of Concept of operation and the identification of vulnerabilities – internal sources of risks and the estimation of their potential impact. The second is the evaluation of answers a questions asked in the scope of EXP 4 (these are the tools of the measurement): the identification of the threats – external sources of risks and the estimation of their severity. The third is the estimation of threats' likelihood with respect to a potentiality (as a function of a natural exposure, an impunity of the potential aggressor and a realisation easiness). The fourth step is the synthesis.
- **Environmental sustainability:** Areas of potential improvement are emissions and noise. In the context of global ECAC-wide simulations there is no possibility to address noise in detail, it is too specific. Performance changes having an impact on the environment will be addressed via the performance of flight paths only.
- **Access and equity**: Optimal ATM service provision was based traditionally on the principle of First-Come First-Served (FC-FS). There are clear indications that there are many conditions under which FC-FS is not the optimal way of service provision. However, alternative priority rules may replace the FC-FS principle only if access and equity is made transparent and measurable, e.g. by accounting weighted values of services. This may be a factor to play a role in performance assessment experiments.
- **Participation by the ATM community:** There is no evidence how this will impact conceptual improvements and how to assess performance assessment aspects.
- **Global Interoperability:** Idem

Indicator Identifier	Area	Answered by ERAMUS	Descriptive name	Definition
KPI_EFF_DEPDELAY_OCC	Efficiency	No	Departure delay (occurrence)	Proportion of departing flights delayed more than 3 minutes at departure
KPI_EFF_DEPDELAY_SEV	Efficiency	No	Total departure	Average departure delay of flight delayed more than 3 minutes
KPI_EFF_DURATION_OCC	Efficiency	Yes	Flight duration extension (occurrence)	Proportion of flights with additional flight duration (compared to their shared business trajectory duration) of more than 3 minutes
KPI_EFF_DURATION_SEV	Efficiency	Yes	Flight Duration Extension (severity)	Average deviation time of flights with additional flight duration (compared to their shared business trajectory duration) of more than 3 minutes
KPI_EFF_FUEL_OCC	Efficiency	Yes	Gate to gate fuel efficiency (occurrence)	Proportion of flights with additional fuel consumption of more than 2.5% of intended consumption
KPI_EFF_FUEL_SEV	Efficiency	Yes	Gate to gate fuel efficiency (severity)	Average additional fuel consumption of flights with additional fuel consumption of more than 2.5% of intended consumption
KPI_PRED_ARRDELAY_OCC	Predictability	No	Arrival delay (occurrence)	Proportion of flights delayed more than 3 minutes at arrival
KPI_PRED_ARRDELAY_SEV	Predictability	No	Arrival delay (severity)	Average arrival delay of flights delayed more than 3 minutes at arrival
KPI_PRED_VARIATION	Predictability	Yes	Temporal variation	Coefficient of variation (standard deviation divided by mean) of gate-to-gate time differences between actual and last agreed values milestone times
KPI_CAP_THROUGHPUT	Capacity	Yes	Throughput	Number of flights exiting an air traffic network node or sub network by unit of time
KPI_CAP_WORKLOAD	Capacity	Yes	(Simulated)	Weighted combination of elementary events workloads
KPI_CAP_ELEMENTARY	Capacity	Yes	Sector capacity	Maximum number of flights exiting a sector per unit of time (e.g. an hour) without exceeding maximum tactical workload
KPI_CAP_OVERALL	Capacity	Yes	Overall system capacity	Maximum number of flights per hour in the ECAC Area taking into account traffic flows and sector capacity restrictions.
KPI_CAP_SCATTERING	Capacity	Yes	(Simulated) workload scattering	Scattering between workload per sector and the saturation threshold (70% ATCo Occupancy Time) *(This is an indicator of sectors capacity utilisation)*
KPI_SAF_PROPENSITY	Safety	Yes	INTEGRA Propensity	Number of times an ATC tactical intervention is needed in order to avoid a potential conflict on air (losses of separation)

KPI_SAF_RESILIENCE	Safety	Yes	INTEGRA Resilience	Ability of the ATM system to respond to that event without increasing the probability of that event
KPI_SAF_SEPLOSSES-OCC	Safety	Yes	(Simulated) air-air separation losses occurrences	Number of simulated air-air separation losses occurrences per unit of time (e.g. one day)
KPI_SAF_SEPLOSSES-SEV	Safety	Yes	(Simulated) air-air separation losses ratio	Cumulated durations of air-air separation losses divided by cumulated flight hours.
KPI_SAF_DENSITY	Safety	Yes	Density	Number of flights per unit of airspace per unit of time (*this indicator is multi-valued*)
KPI_SAF_OVERLOADS	Safety	Yes	Workload over ratio	Number of hours with workload overloads
KPI_ENV_OVERALLFUEL	Environmental Sustainability	Yes	Overall fuel consumption	Average mass of fuel per unit of time (e.g. per day)

4.4 Arguments description

(76) ERASMUS shall provide a set of arguments in order to deliver information on the performance issues and on the system description which are not covered by the KPA/KPI approach. Enough validation demonstration must be done to ensure that the concept is viable technically and operationally, and acceptable by users.

(77) The overall arguments shall be developed:

- Arg 1: Safety Argument : ERASMUS is acceptably safe in principle,
- Arg 2: Operational Argument : ERASMUS is operationally efficient and fit an operational need,
- Arg 3: ERASMUS is acceptable by users,
- Arg 4: ERASMUS is technically feasible,
- Arg 5: ERASMUS is acceptably secure,
- Arg 6: ERASMUS is economically viable,
- Arg 7: ERASMUS is environmentally compliant.

(78) The detailed arguments shall be developed.

- Arg 1: Safety Argument : ERASMUS is acceptably safe in principle:
    - Arg 1.1: Safety functions and objectives specify what is sufficient for ATM service to meet safety targets;
    - Arg 1.2: Safety requirements specify what is sufficient to enable safety targets to be met
    - Arg 1.3: Safety requirements are potentially achievable;
    - Arg 1.4: Sufficient measures taken by project team to enable consistent implementation of ERASMUS safety requirements by partners;

  - Arg 1.5: All assumptions have been recorded and validated;
  - Arg 1.6: All issues regarding satisfaction of the safety requirements have been addressed;
- Arg 2: Operational Argument : ERASMUS is operationally efficient and fit an operational need:
  - Arg 2.1: Operational procedures have been developed and tested;
  - Arg 2.2 : Operational requirements specify how ERASMUS should be used;
  - Arg 2.3: Operational requirements are potentially achievable;
  - Arg 2.4: Sufficient scenarios of potential degraded and unusual situations have been tested to ensure enough robustness of ERASMUS procedures;
  - Arg 2.5: All assumptions have been recorded and validated;
  - Arg 2.6: All issues regarding satisfaction of the operational requirements have been addressed;
- Arg 3: ERASMUS is acceptable by users:
  - Arg 3.1: Working methods (role, task, responsibility) are accepted by users;
- Arg 4: ERASMUS is technically feasible:
  - Arg 4.1: Technology is identified to support all the elements of the concepts;
  - Arg 4.2: Technical requirements to support ERASMUS concept are properly described;
  - Arg 4.3: Technical solutions are tested and viable;
  - Arg 4.4: Integration of technical elements is properly considered;
- Arg 5: ERASMUS is acceptably secure;
- Arg 5: ERASMUS is acceptably secure:
  - Arg 5.1: The date was identifier and classified;
  - Arg 5.2: The internal sources (vulnerabilities) and the external sources (threats) of risks were considered (*not yet at the moment*);
  - Arg 5.3: The risks were assessed (*not yet at the moment*);
  - Arg 5.4: The security objectives were specified (*not yet at the moment*);
  - Arg 5.5: The procedural and technical solutions were recommended (*not yet at the moment*);
  - Arg 5.6 Security solutions are potentially achievable;
- Arg 6: ERASMUS is economically viable:
  - Arg 6.1: Technical and Operational solutions are able to provide tangible Benefits;
  - Arg 6.2: Technical and Operational solution implementation does require sustainable costs;
- Arg 7: ERASMUS is environmentally compliant:
  - Arg 7.1: No additional impact on noise (en route), specifically for sonic boom (specific case not addressed);
  - Arg 7.2: Speed adjustments are minor (less than 6%) and impacts on fuel consumption per flight are not significant;

- Arg 7.3: Time adjustments on the 4D trajectories minimise the lateral deviations and improve lateral efficiency;
- Arg 7.4: Impacts on environment, and more specifically the atmospheric issues such as gaseous emissions, are assessed during FTS and Human-in-the-loop simulations.

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5 THE OPERATIONAL CONCEPT

5.1 Concept Overview

(79) This section describes the actual concept developed in the ERASMUS Programme.

(80) The future ATM system must be able to cope with the expected growth in traffic. This will be achieved by designing and managing a system that is service-oriented (i.e. provider of services) and based upon a common framework or information network. This new system is described in the SESAR Milestone Deliverables. SESAR is the European Commission's proposed approach to modernise the ATM structure in Europe with the objective of achieving a future European ATM system for 2020 and beyond which can, relative to today's performance: enable a 3-fold increase in capacity which will also reduce delays, both on the ground and in the air; improve the safety performance by a factor of 10; enable a 10% reduction in the effects flights have on the environment; and provide ATM services at a cost to the airspace users which is at least 50% less.

(81) The SESAR vision is dependent on 3 distinct ATM frameworks, to which all stakeholders have to commit and operate: the Performance framework, the Business management framework, and the Institutional and Regulatory framework.

(82) The Performance framework is composed of 11 Key Performance Areas, which are the working assumptions that need to be validated. The relation of ERASMUS to these KPAs will be discussed in Chapter 3.

(83) The Business management framework refers to a service-oriented approach to the definition and management of the ATM system and is centred around the idea of the Business trajectory. The Business trajectory represents an airspace user's intention with respect to a given flight.

(84) Although the Institutional and Regulatory framework is beyond the scope of this document, it is important to mention that with changes in roles and responsibilities this framework will support a new definition of liability and sharing between the different agents of the system (e.g. ANSPs, pilots, manufactures, etc.).

(85) The Business Framework includes the implementation of the Business trajectory concept, which is one of the main changes that characterises the future ATM system according to the SESAR programme. The Business trajectory is the representation of an airspace user's intention with respect to a given flight. It is aimed at guaranteeing the best outcome for the flight, in terms of cost, flight time, etc., as seen from the airspace user's perspective. Once defined by the airspace user it is shared with the relevant stakeholders, updated and accepted by the service providers as the RBT (Reference Business Trajectory)

(86) The RBT is the trajectory the airspace user agrees to fly and the ANSP airports agree to facilitate, subject to separation provision. The way it is first defined, shared and then facilitated is referred to as the Trajectory Management.

(87) Changes are made to it only when it is necessary to comply with unavoidable airspace/airport constraints or other external constraints (e.g., weather), but the user's preference remains as the main driver. The implementation of this framework implies a move from airspace-based operations to trajectory-based operations. This means that much better (i.e. precise) planning will lead to flight plans that will need fewer tactical changes, and thus a different role for controllers, who will work less through tactical intervention and more through strategic planning and decision-making.

(88) The design of the airspace to match the trajectory-based management approach will be crucial in

permitting the ATM System to provide the right services, at the right time and in the right places. Controller task-load per flight is a major factor in airspace capacity. The ATM Target Concept will increase capacity by reducing the controller workload per flight (decreasing routine tasks and the requirement for tactical intervention). In highly congested areas this will be achieved by deploying route structures that provide a greater degree of strategic de-confliction and procedures that capitalise on the greater accuracy of aircraft navigation. New separation modes supported by controller tools, utilising shared high precision trajectory data, will increase the valid duration of each clearance. Tools will also support task identification, clearance compliance and monitoring. Further reductions in controller workload per flight can be expected from air/ground data link communications and the delegation of some spacing and separation tasks to the pilot.

(89) To address these issues, ERASMUS will investigate a new separation mode : TC-SA (Trajectory Control by Minor Speed Adjustment). In order to generate conflict-free segment (15 min), ERASMUS propose real-time 4D Business Trajectory adjustment based on aircraft minor speed modification.

(90) To manage separations between planes (e.g., maintain a separation of > 7 Nm in 20 minutes time windows), ERASMUS will automatically issue clearances that direct minor adjustments to the horizontal or vertical speed of the planes (-5%, +2% of current speed). These adjustments will be so small that they will not be perceptible by controllers and therefore, will not 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

(91) In SESAR airspace will be divided into managed and unmanaged, which corresponds in principle to controlled and uncontrolled airspace, but whereas today the pilot is responsible for visual separation in uncontrolled airspace, tomorrow's uncontrolled airspace may be much wider and the pilot will be responsible for self-separation using tools and not only visual sight.

(92) The key aspect considered in managed airspace is the number of interacting trajectories. A high number of interacting trajectories is perceived by the controller as high complexity because it represents a high task load to resolve. If the interactions are spread randomly across the area of responsibility, that also increases perceived complexity because the monitoring task can not rely on experience and pattern recognition.

(93) Even with advanced automated support for conflict detection and resolution and conformance and intent monitoring, the controller will still be required to validate solutions and execute them at appropriate times. The validation of system-provided resolutions requires that the controller must retain sufficient Situational Awareness (SA), possibly limited to and focused on the given problem, to be able to make those decisions, however SA can also be supported by the system.

(94) The goal of the SESAR concept is to deploy tools to assist the controller with complex situations and to reduce complexity by strategic de-confliction measures where necessary to increase capacity. The reduction of complexity is planned to be carried out with the assistance of appropriate automation that achieves the goal with minimum distortion of the trajectories concerned.

(95) ERASMUS provides strategic de-confliction by resolving conflicts 20 minutes in advance. It reduces the complexity of airspace by reducing the number of conflicts and by increasing the minimum separation between aircraft, thereby providing more flexibility to the controller through a traffic flow that may be easier to manage.

(96) The other main service to be delivered to airspace users, as defined by SESAR is the Conflict Management service.

(97) In today's system conflicts can be reduced to an extent by airspace design but primarily through the preparation work by the Planning Controller and tactical work by the Tactical Controller. In future systems the role planned by the design of the airspace and route will be increased in reducing conflicts,

in that the RBT will be accepted by the service provider also on the basis of safety criteria (i.e. it will be designed so as to reduce number of conflicting situations). Regarding the controllers, although their role will change, they will remain the main actors in separation assurance, even when they decide to delegate this task to pilots.

(98) The function of conflict management is to limit, to an acceptable level, the risk of collision between aircraft and hazards. Conflict management is applied in 3 layers, which are defined in terms of time, from further away from the conflict, to closer in time to the conflict: strategic conflict management, separation provision, and collision avoidance.

(99) Strategic conflict management aims at reducing the need to apply separation provision and thereby reducing tactical controller workload. The separation provision is the tactical separation assured in real-time operations. Collision avoidance is the last-resort method of conflict management, in that it is triggered by an alarm (STCA or TCAS).

(100) With the substantial traffic increase expected the controller's task load will become unmanageable without implementing substantial changes to help the controller assure this task.

(101) In order to meet the performance targets set for the future ATM System, it is envisaged that the future ATM Target Concept will shift from an approach, which is based upon a "management by tactical intervention" approach, to a more strategic one, which is "management by planning and tactical intervention by exception". This approach is based on 3 assumptions. The first is that routine tasks (e.g. coordination, routine communications, data management) will be supported by better methods of data input and improved data management. The second is that there will be automation support for conflict detection, conflict resolution, and situation monitoring. The third regards the fact that the number of potential conflicts will be reduced and thus so will the need for tactical intervention.

(102) Although a greater degree of automation will be required, the human will remain the most flexible and creative element to manage the overall System, including responding to threats, errors and unpredictable events.

(103) ERASMUS supports this approach because it plays a role in the second and third assumptions described above. Regarding the third assumption, ERASMUS will reduce the number of conflicts and thus support a reduction in tactical interventions. With regard to the second assumption, the strategic de-conflicting will feed precise data to conflict detection tools, so as to correctly highlight to controllers the situations that need to be addressed. ERASMUS can play a role in the detection resolution by providing in a first moment solutions through small speed changes. In a second moment it is expected that ERASMUS will be able to provide resolutions also in terms of heading or level change. If we imagine a SESAR-compliant scenario in a managed airspace, with aircraft flying their RBT, the conflict detection tools should only show aircraft that exceptionally deviate from their path. The strategic de-conflicting will also be able to provide, through a conflict resolution tool, information on how to best resolve these conflicts, so as not to create new ones and, most importantly, so as to provide a new segment of conflict-free route for the aircraft.

5.2 Assumptions

5.2.1 Solutions to the complexity problem

(104) The ERASMUS project has chosen to reduce the complexity by reducing the controller uncertainty using the following strategies:

- Changing the traffic distribution (transfer of aircraft from "conflicting" to "no conflicting" situations).
- Improving the traffic prediction information (high-precision information provided to the controller).
- Improving system automation tools enabling the shift from tactical intervention to strategic de-confliction

5.2.2 Solutions to the Human-Machine interaction problem

(105) ERASMUS investigates three solutions related to the Human – Machine Interaction problem:

- Act on the levels of information and autonomy: ERASMUS assesses two combinations of information and autonomy parameters in order to attempt to find an optimum balance (in terms of task allocation) between the human and the machine.
- Assess the impact on on-board side: ERASMUS requires specific onboard equipment and specific inputs and procedures for the pilots.
- Address the responsibility issue: ERASMUS must clearly define the extent to which the responsibility, and the related procedures, is shared between the agents.

5.3 Technical requirements

(106) This paragraph identifies a first level of requirements for the implementation of the ERASMUS concept. The requirements are complemented by associated hypotheses which describe the initial values of parameters or operator's role that will be validated during the ERASMUS programme.

(107) From a technical point of view, ERASMUS 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 (Figure 3).

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

- A Trajectory Prediction (TP) function that provides an estimated 4D trajectory computation for the next 20 to 30 minutes.
- A Trajectory Contracting function that allows the ATC ground system to set speed or time constraints on the 4D flight profile and a way to check that the modification done does not create other conflict situation.

(109) 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 tactical controllers are likely to intervene if no strategic conflict resolution are performed.
- A Conflict Resolution function that implements when possible a strategic conflict resolution strategy based on minor speed alterations or RTA constraints in a transparent way for the controllers. The Conflict resolution is also able to propose alternate resolution strategy based on the use of route change and/or level change. These alternate strategies can be assessed by operators via a set of ERASMUS User's services.
- The User's services enable an ATM actor to assess the proposed Route/Level change strategies or its own strategies.

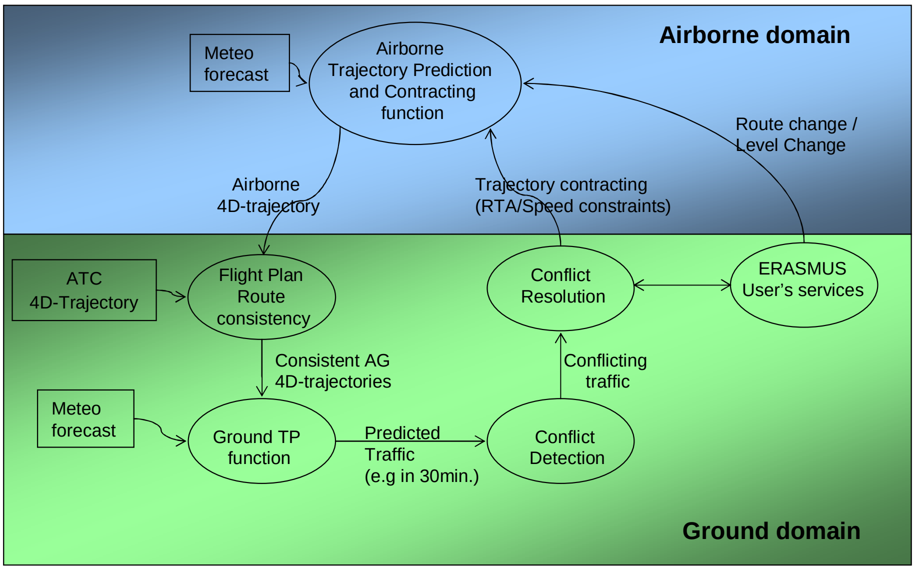

Figure 3 : ERASMUS – Functional Architecture

(110) The high-level processing performed by these functions description is given below (see Figure 4).

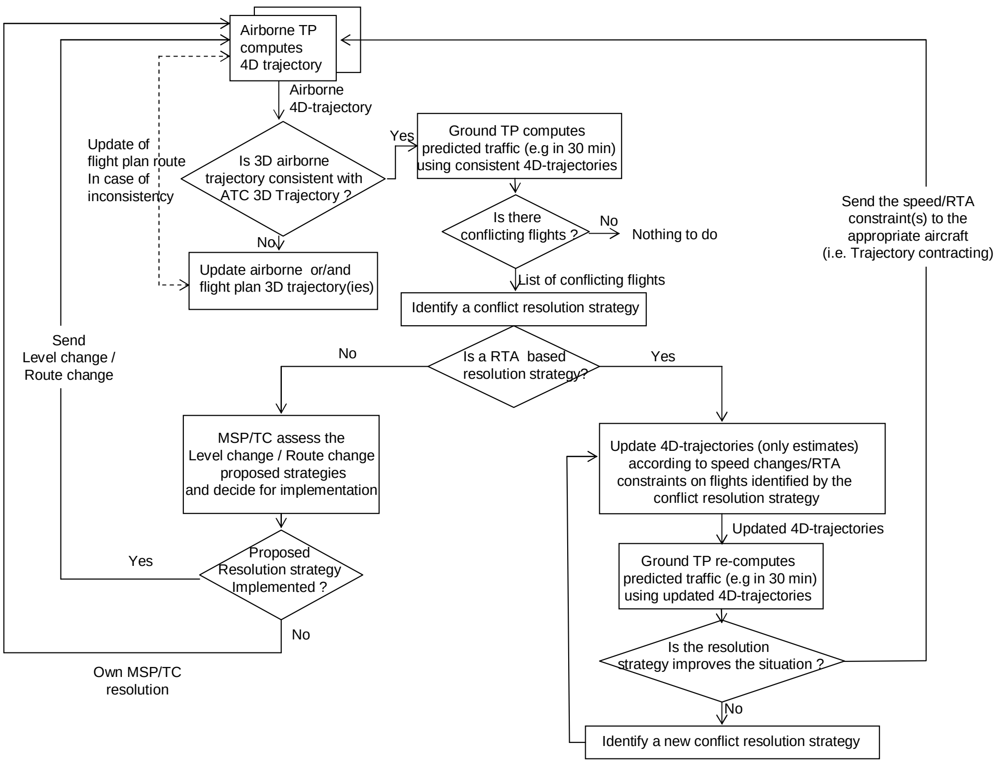

Figure 4 : ERASMUS – Process description

(111) The initial level of requirements (REQ) and hypotheses (HYP) identified ERASMUS are as follows:

5.3.1 Requirements and Hypotheses applicable to Trajectory prediction

REQ-01	Meteorological information (wind speed & wind direction at different altitudes and temperature …) shall be provided to the Air Trajectory Prediction function with sufficient accuracy, resolution and frequency.

HYP-01	The meteorological forecast data will be updated every 30 to 60 minutes and uplinked to the aircraft.

REQ-02	Meteorological information (wind speed & wind direction at different altitudes …) shall be provided to the Ground Trajectory Prediction function with sufficient accuracy, resolution and frequency.

HYP-02	Sensed meteorological data will be downlinked every 1 to 10 minutes.

REQ-03	Available meteorological information shall be used for the computation of the aircraft flight trajectory predictions, by both the Air and Ground Trajectory Prediction functions.

HYP-03	Standard deviation in wind prediction errors should be no more than 4-5m/s.

REQ-04	The downloaded 4 D trajectory data content, data accuracy and transmission frequency shall be sufficient to enhance the ground trajectory prediction accuracy necessary for the implementation of the ERASMUS Strategic De-conflicting application.

HYP-04	The downlinked 4D Air Trajectory Prediction may consist of a list of active flight plan points, aircraft state and intent data, aircraft performance parameters for construction of speed profile, sensed local weather data and the RNP accuracy (on each point) corresponding to the next 20 to 30 minutes of flight.

REQ-05	Consistency between air trajectory predictions and ground trajectory predictions shall be ensured.

HYP-05	Ground Trajectory Prediction and Air Trajectory Prediction must be within a 10 to 30% margin, depending on phase of flight, at least 95% of the time, both spatially and temporally.

REQ-06	Potential conflicts shall be detected and resolved within a time margin that allows the aircraft to adjust its flight path in a manner that remains within acceptable limits. (Speed tolerance window, passenger comfort, etc.)

5.3.2 Requirements and hypotheses applicable to Speed/RTA based conflict Resolution

HYP-06	The Speed/RTA based conflict resolution manoeuvres should provide the aircraft with 5 to 20 minutes of flight time in which to meet the contracted flight (speed, RTA) constraint.

HYP-07	The Speed/RTA based conflict resolution strategy shall be determined using speed variations bounded between [-12% to -3%] and [+3% to +6%] of the current aircraft speed and checked for speed envelope compatibility.

HYP-08	The Speed/RTA based conflict resolution strategy shall be initiated for aircraft that are detected with minimum spacing of between 5 to 10 NM between aircraft anytime in the next 5 to 20 minutes of flight.

REQ-07	The uplinked speed or RTA constraint shall be automatically uploaded to the airborne system (e.g., CCL, FMS) and inserted into the active flight plan upon pilot acceptance.

REQ-08	The aircraft shall adhere to the "contracted" RTA constraints within acceptable tolerance margins (to be determined by ERASMUS research).

HYP-09	The spatial error for the Air Trajectory Contracting (RTA, speed) function may not exceed 0.5 to 2NM from its contracted position, 95% of the time, when given a time window of 5 to 20 minutes to adjust the aircraft's flight path.

HYP-10	The temporal error for the Air Trajectory Contracting (RTA, speed) Function should be no more than 4 to 12 seconds, 95% of the time, when given a time window of 5 to 20 minutes to adjust the aircraft's flight path.

REQ-09	The aircraft shall downlink a "cannot comply" when a RTA or speed constraint can not be met. The aircraft will also notify ATC when a previously accepted RTA or speed constraint can no longer be achieved, even if previously accepted.

5.3.3 Requirements and hypotheses applicable to Route/Level change based conflict resolution

REQ-10	The user shall be able to request the system to provide at least one conflict resolution through the designation of a conflicting pair of aircraft.

REQ-11	On this user request, the system shall identify at least one conflict resolution using : - a level change on one of the two aircraft, - or a route change on one of the two aircraft, - or a level change for one aircraft and a route change on the other one.

REQ-12	The conflict resolution based on Route/Level change shall only be applied on controller request.

5.3.4 Requirements and hypotheses applicable to ERASMUS User's Services

REQ-13	The system shall display all conflicting aircraft by pairs.

REQ-14	On a specific position, the system shall display only conflicting aircraft for a set of 2-4 sectors. (i.e. non-conflicting aircraft are not displayed on this position). These conflicts correspond to the conflicts that have not been solved by a conflict resolution based on Speed/RTA.

HYP-11	The specific position mentioned in REQ-14 is dedicated to a MSP.

REQ-15	On user request, the system shall be able to display the speed constraints applied by the Speed/RTA based conflict resolution.

REQ-16	On user request, the system shall be able to display the guaranteed distance between two aircraft.

REQ-17	The system shall enable the user to assess all conflict resolutions based on Route and/or Level change. For that, graphical tools and "what-if" function shall be provided to display how the conflict is solved.

REQ-18	The system shall enable the user to assess its own resolution strategy.

REQ-19	The system shall provide a workload/complexity indicator per sector for the next 20 minutes.

HYP-12	The workload/complexity indicator corresponds to the number of conflicts to be managed in a given sector.

HYP-13	The workload/complexity indicator will be used by a Multi-Sector Planner. This information will be used to choose a resolution strategy impacting tactical controllers having a low/acceptable workload. MSP will thus request a TC for the implementation of a strategic conflict resolution only when the TC can perform the action.

REQ-20	The system shall alert a specific user when a workload/complexity threshold is raised.

HYP-14	The MSP will be this specific user. When the workload/complexity threshold is raised for a sector, the MSP will take some appropriate actions (e.g. sector re-configuration)

5.4 ERASMUS expected benefits

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:
- Complexity management actions will have no effect on lateral/vertical trajectories. Time-based impacts should be limited. Overall, ERASMUS will facilitate effective airspace management while still allowing airspace users to choose the trajectories that best suit their business needs.
- 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)

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6 Programme influences and objectives

6.1 The programme objectives

(112) The strategy to identify the ERASMUS project objectives is based on a dual approach, top down and bottom up.

- The top-down approach will ensure that the project is SESAR performance-driven. During the project, the ERAMUS targets levels of performance will be identified and agreed with stakeholders in order that real improvements can be achieved and measured.
- The bottom-up approach will fulfil the need for filling the gap which has been identified during the consultation phase of the project. (operational requirements, resolution of human factors issues, safety requirements…).

6.2 Programme stakeholders

Stakeholder	Involvement	Priorities
Airspace users	Airspace users with their requirements for access to the airspace, predictability of operations and demands for lower operating costs want to drive the performance aspects	Verify benefits achieved following implementation by ANSP's
ANSPs	The implementation of ERASMUS capability by ANSP's is essential to the success of the project. However they need to take their local objectives and constraints into account. ANSP's will be able to demonstrate to their customers, the airspace users, that they are striving to achieve early benefits and satisfy user requirements	To assist ANSP's by helping to technical and operational understanding support
Military	Where dual civil and military services exist similar capabilities need to be ensured	Ensure proper interaction with military procedures
ATC regulators	ATC regulators will provide the operational approval for new systems and operations	To permit an early understanding of the technical, operational and safety requirements associated with such implementation
Industry	Industry has a key role to play by developing and delivering the ATC systems to ANSP's	Understand ERASMUS implementation issues
European Commission – JU SESAR	The European Commission and the JU SESAR have an important role to integrate the ERASMUS project into the baseline for SESAR	Need for strategy harmonisation

6.3 ERASMUS Programme dependencies

(113) In order to reliably predict aircraft separation between aircraft on the medium-term – typically 20 minutes in advance – there need to be a sufficiently accurate and stable trajectory prediction.

(114) TP is expected to be part of new generation FDPS – hence there is dependency to the introduction of

the new FPDS.

(115) ERASMUS needs to be integrated into local controller working positions and MSP function.

6.4 Other influences

(116) Currently the SESAR road map is under development through the common European Commission and SESAR programme. The SESAR definition phase will be completed end of 2008. ERASMUS has to be synchronised with SESAR.

(117) The ERASMUS project shall be aligned with the SESAR strategy.

7 The validation expectations and objectives

(118) ERASMUS programme is led by the KPA/KPI defined in the SESAR programme. The aim is to make a clear and strong link between these KPA/KPI and ERASMUS project objectives.

(119) An attempt to sketch a schematic view of the process is presented in the figure below.

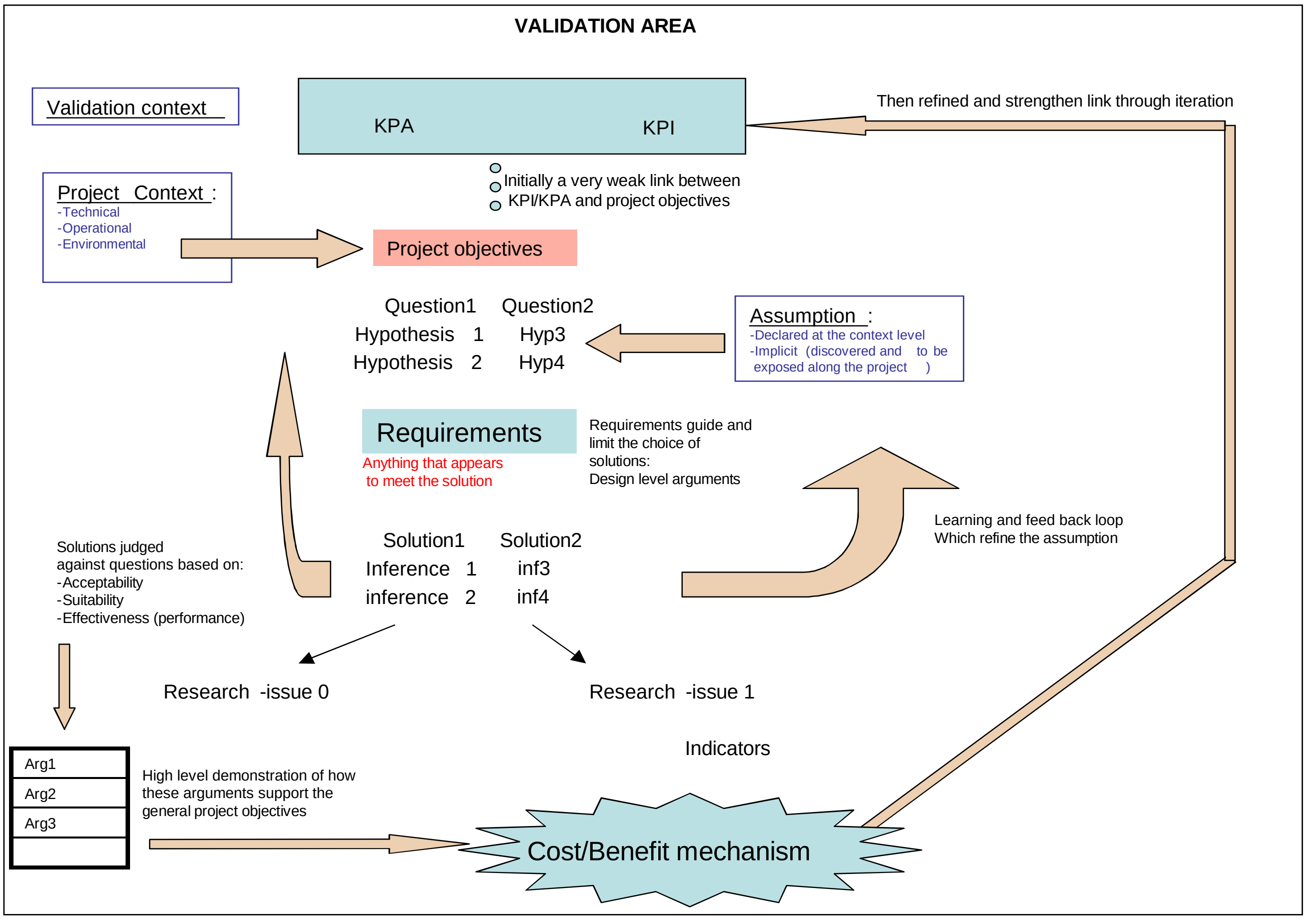


Figure 5: Matrix for Validation

(120) The matrix above represents the link between the elements involved in the validation process such as KPA/KPI, objectives, questions, hypotheses, assumptions, requirements, solutions and arguments.

(121) Initially the project objectives have a weak link with the KPA/KPI from common sense. These objectives are decomposed into high level objectives based on initial constraints and take into account what is initially known about the context of the project.

(122) Some hypotheses are made and requirements for potential solutions needed to be tested are inferred, these requirements guiding and limiting the choice of solutions. Research questions and arguments are derived from each solution about what will be done. To do so a study has to be carried out using relevant indicators. The arguments can then go to a benefit mechanism to determine the level of contribution (positive and negative) to a KPA based on KPI. From this knowledge the view of the project goal can be updated and the link between the indicators and the KPA/KPI can be refined through iterations.

7.1 Supporting cases required

(123) The validation process using the case-based approach will cover Safety, HF, business aspects. These cases will serve as input to the validation plan and raise questions to be addressed throughout the validation process.

(124) The ERASMUS Validation Objectives are stated in 4.1. To achieve these objectives, the validation need to provide evidence for the following cases:

- Safety;
- Security;
- Environment;
- Cost Effectiveness;
- Capacity;
- Efficiency;
- Flexibility;
- Predictability;
- Access and Equity;
- Participation;
- Interoperability.

7.2 Programme validation objectives

(125) The tables below summarise the programme validation objectives. Each table shows how an ERASMUS solution is addressed through hypothesis to validate, research questions to investigate and indicators to measures.

7.2.1 Operational and Human Factors Issues

Solutions to complexity problem	Hypotheses	Research Questions	Indicators
Act on traffic complexity delivered to controller (i.e. change traffic distribution)	Situations of “doubt” and “no doubt” do exist for the controller.	**R1** Are there doubt situations?	Risk perception, safety feeling, difficulty feeling.
	Reducing controller uncertainty will conserve mental resources.	**R2** Does it save mental resources? Does it allow to improve the human performance?	Compare number of aircraft considered with number of aircraft not considered whereas they should be (safety).
Improve traffic prediction information	Reducing controller uncertainty will conserve mental resources.	**R3** Does the improvement of the conflict information quality will conserve mental resources?	Risk perception, safety feeling, difficulty feeling.
	Reducing number of conflicts will conserve mental resources.	**R4** Does it save mental resources? Does it allow to improve the human performance?	Compare number of aircraft considered with number of aircraft not considered whereas they should be (safety).

Solutions to H–M interaction problem	Hypotheses	Research Questions	Indicators
Provide an autonomous system	ATCO will not be disturbed by the minor a/c speed variations computed by technical system	**R5** Is ATCO disturbed by modification of a/c trajectories?	Statement of dissatisfaction / frustration Excessive confidence or non confidence
		R6 Do modifications generate added communications between ATCO & pilot?	Nb of ATCO – Pilot communications
		R7 Do modifications create different understanding from ATCO & pilot?	Content of ATCO – Pilot communications
		R8 Are there interferences between TS strategy & operators' strategy?	Nb of technical system actions interrupted
Provide an efficient interactive system	A dedicated HMI can provide info to reduce doubt without disturbing ATCO task performance or cognitive activities	**R9** Does the HMI provide an efficient environment for the operators?	????
Assess impact on on-board side	ERASMUS integration into the cockpit is acceptable and will not overload the pilot	**R10** Is it acceptable for pilot to receive an order coming from a machine instead of an ATCO?	Rate and reasons of technical system actions carried out by the pilot
		R11 Does the integration of ERASMUS in the cockpit overload the pilot? And are pilots disturbed by ERAMUS generated modifications?	Verbalisation (workload)
Address responsibility issue and Role change	ERASMUS needs to be certified to be acceptable to the operators	**R12** How to address the responsibility transfer and role change issues?	Paper Study

7.2.2 Technical Issues

Solutions to technical issues	Hypotheses	Research Questions	Indicators

Solutions to technical issues	Hypotheses	Research Questions	Indicators
Impact of meteorological data on the air trajectory prediction	REQ-01 and HYP-01	**R13** What is the impact on Air Trajectory Prediction accuracy as a result of periodic meteo forecast uplinks during the flight?	Metric: Prediction accuracy at a given time horizon t and with a p periodicity for the meteo uplink A(t,p) Accuracy Difference (t) = A(t,p) – A(t,0) Indicator: Measure accuracy differences between FMS prediction accuracy generated without the use of meteo forecast uplinks and FMS prediction accuracy generated with meteo uplink forecast.
	REQ-01 and HYP-01	**R14** Will more frequent updates of meteo forecast data improve the accuracy of the air Trajectory predictions? If yes, by how much?	Metric: Prediction accuracy at a given time t horizon and with a p periodicity for the meteo uplink A(t,p). p' = more frequent update Accuracy Difference (t) = A(t,p) – A(t,p') Indicator: Measure accuracy difference between two FMS predictions using different meteo forecast uplink rate.
	REQ-01 and HYP-01	**R15** What benefits does the increased meteo information accuracy provide to the stakeholders? (Airlines, ATM…)	Indicator: Assessment of savings (costs, workload, etc.) for stakeholders.
Identify air/ground data to be exchanged and the associated datalink solution	REQ-04 and HYP-04	**R16** Are existing datalink standards and technology sufficient to provide the data exchange deemed beneficial on ERASMUS?	Metric: presence of required data, data resolution, adequate periodicity. Study of existing standards and technology.
	REQ-04 and HYP-04	**R17** What is the most effective way to transmit an aircraft's speed profile?	Metric: presence of required data, data resolution, adequate periodicity. Study of existing standards and technology.
	REQ-01 and HYP-01	**R18** What is the most effective way to transmit weather data to aircraft? What are the data to be transmitted?	Identify the impact of each weather data on the air trajectory prediction accuracy. (metric : loss of accuracy when a given meteo data is not used) Study the possible datalink solution. (metric: existence of datalink solution, cost for a new solution)

Solutions to technical issues	Hypotheses	Research Questions	Indicators
	REQ-02 and HYP-02	**R19** What is the most effective way to transmit weather data from aircraft to the ATC ground system? What are the data to be transmitted?	Study the possible datalink solution. (metric: existence of datalink solution, cost for a new solution) Identify the impact of each weather data sent by aircraft on the ground trajectory prediction accuracy.
	REQ-07	**R20** Can an updated version of CPDLC enable the RTA constraint to be automatically uploaded to the airborne system? Does this uplinked RTA constraint provide enough detail so that it can be directly inserted into the active flight plan upon pilot acceptance? Is the definition of a new datalink application required?	Metric: Study the CPDLC technology. (metric: existence of datalink solution, cost for a new solution)
Improve ground trajectory prediction	REQ-04 and HYP-04	**R21** What is the impact on Ground Trajectory Prediction accuracy as a result of individual downlinked aircraft parameters?	Metric: Prediction accuracy at a given time horizon t AccuracyDiff (t) = GTP_without_AC_params (t) – GTP_with_AC_params(t) Indicator: Measure accuracy differences between Ground Trajectory Prediction (GTP) accuracy generated without downlinked aircraft parameters and GTP accuracy generated using downlinked aircraft parameters.
	REQ-04 and HYP-04	**R22** What set of downloaded aircraft parameters provide the greatest gain in Ground Trajectory prediction accuracy?	Metric: Prediction accuracy at a given time horizon t AccuracyDiff (t, param) = GTP_without_AC_params (t) – GTP_with_AC_param(t, param) Indicator: Measure accuracy differences between Ground Trajectory Prediction (GTP) accuracy generated without downlinked aircraft parameters and GTP accuracy generated using a given aircraft parameters.
	REQ-04 and HYP-04	**R23** Is aircraft performance data (e.g RNP, cruising speed) available on ground databases such as BADA, sufficient to meet HYP-05 ?	Indicator: Data available on ground databases as an input into GTP to meet ERASMUS accuracy requirements.

Solutions to technical issues	Hypotheses	Research Questions	Indicators
	REQ-02 and HYP-02	**R24** What is the impact on Ground Trajectory Prediction accuracy as a result of periodic meteo downlinks during the flight?	Metric: Prediction accuracy at a given time horizon t and with a p periodicity for the meteo downlink A(t,p) Accuracy Diff (t) = A(t,p) – A(t,0) Indicator: Measure accuracy differences between Ground Trajectory Prediction (GTP) accuracy obtained without the use of meteo downlink and GTP accuracy obtained with meteo downlink.
	REQ-03 and HYP-03	**R25** What is the impact to Ground Trajectory Prediction accuracy if wind prediction errors are more than 2-3m/s ?	Metric: Prediction accuracy at a given time horizon and q quality for wind prediction errors < 2-3m/s and q' for wind predicton > 2-3m/s ; Accuracy Diff (t) = A(t,q) – A(t,q') Indicator: Measure accuracy differences between Ground Trajectory Prediction (GTP) accuracy obtained using "correct" wind (i.e < 2-3m/s) and GTP accuracy obtained with "inaccurate" wind (i.e > 2-3m/s) downlink.
	REQ-04 and HYP-04	**R26** What is the overall benefit of this increased ground-based Trajectory Prediction accuracy?	Metric: Number of false MTCD alarm, Number of effective conflict resolution. Indicator: Compare the number of false MTCD alarm obtained with this enhanced GTP with the number of false MTCD alarms obtained with the initial GTP. Compare the number of effective conflict resolution obtained with this enhanced GTP with the number of effective conflict resolution obtained with the initial GTP.
Behaviour of Conflict detection function	REQ-05 and HYP-05	**R27** What is the impact on the Conflict Resolution results if trajectories predicted by airborne trajectory predictors (TP) and ground-based TP's deviate more than 10 to 30% from each other?	Metric: Number of false MTCD alarm, Number of non-effective conflict resolution. Indicator: compare the number of effective and non-effective conflict resolution obtained with good airborne and ground TP's with effective and non-effective conflict resolution obtained with airborne and ground TP's deviating more than 10 to 30% from each other.

Solutions to technical issues	Hypotheses	Research Questions	Indicators
Define/Assess Conflict resolution strategy	REQ-06 and HYP-07	**R28** Do speed variations between [-12% to -3%] and [+3% to +6%] of the average cruising speed fall within the airline recommended speed changes?	Indicator: Perform a study on this topic, which include airlines consultation and cost effectiveness study based on simulation if needed.
	REQ-06 and HYP-06	**R29** What is the impact of various parameters (time window to detect & de-conflict the airspace, speed variation used for resolution, aircraft type being managed (max. cruising speed), on aircraft spacing achievable with ERASMUS subliminal control action?	Indicator: Perform a study on this topic, which include results of accuracy and sensitivity study.
	REQ-06 and HYP-06	**R30** What is the range of RTA errors under several combinations of flight time, airspeed adjustment, for several aircraft types flying in European airspace? (e.g., Air France/KLM fleet).	Indicator: Perform a study on this topic, which include results of accuracy and sensitivity study. Indicator: equations (conditions)
	REQ-06 and HYP-06	**R31** Given various wind errors, what are the recommended time window and speed/RTA constraints that provide the needed Ac separation?	Metric : validated time window , speed constraints, RTA constraints Indicator: Assessment based on air/ground simulations.
Define/Assess trajectory prediction function	REQ-06 and HYP-06	**R32** Can we mathematically model the ability for an aircraft to meet the required constraint, given the time window, cruise speed flexibility, and needed aircraft spacing?	Indicator: Perform a study on this topic, which include FMS core performance functions analysis.
	REQ-08 and HYP-09	**R33** What is the required navigation performance (RNP) to meet the required aircraft separation upon completion of the ERASMUS action?	Metric : validated RNP value Indicator: Assignment of RNP values to required aircraft separation demands.
	REQ-07	**R34** Is Multiple –RTA concept needed to meet ERASMUS requirements?	Indicator: Assessment of single RTA efficiency to build an efficient Conflict Resolution function.
Assess existing aircraft equipments and standards	HYP-11	**R35** Is the Air Trajectory Prediction and Contracting performance (accuracy, integrity) of current aircraft equipped with modern FMS sufficient to implement the Subliminal Control application?	Indicator: Perform a study to assess if ground trajectory prediction and conflict resolution required performance are achievable with aircraft equipped with modern FMS.

Solutions to technical issues	Hypotheses	Research Questions	Indicators
	HYP-11	**R36** What is the minimum percentage of RTA /speed constraint capable aircraft needed to obtain initial ERASMUS benefits?	Metric: percentage of equipped aircraft needed to obtain first benefits. Indicator : Perform a theoretical study on this subject
	HYP-11	**R37** What is the percentage of fleet already equipped with FMS having RTA capability in the European core area?	Indicator: Perform a study on the fleet operating in Europe.
	HYP-12	**R38** Is the RTA capability on current aircraft sufficient for the implementation of subliminal control application?	Indicator: Perform a study to assess if ground trajectory prediction and conflict resolution required performance are achievable with current RTA capability.
	HYP-13	**R39** Is ADS-B an acceptable communication mechanism to implement the Subliminal Control concept?	Indicator: perform a paper study on this topic.
	HYP-13	**R40** Do existing ADS-B equipped aircraft report prediction data including aircraft state parameters (e.g CAS, intent)? If yes, is this data accurate enough to compute a ground trajectory prediction with sufficient accuracy in respect to Subliminal Control application?	Indicator : data downlinked
	HYP-14	**R41** Do existing CPDLC standards enable the transmission of RTA clearances?	Indicator: Analysis of standards, existence of required messages.
	HYP-15	**R42** Identify and quantify the drawbacks of using fixed prediction accuracy per a/c type for the conflict resolution function.	
	HYP-15	**R43** Identify and quantify the drawbacks of using fixed speed envelope for the conflict resolution function	

7.2.3 Efficiency, Capacity and Predictability Issues

(126) The following statements are dealing with the general approach to use KPIs and metrics

- **Traffic delay analysis**: Determination of traffic load, average traffic load, maximum load and spread (variability of traffic load per airspace volume). (KPI_EFF_DURATION_OCC, KPI_EFF_DURATION_SEV)
- **Traffic throughput**: Determination of throughput and how to address capacity on fully loaded bottleneck hot spots of the network. (KPI_CAP_THROUGHPUT).

- **Flight predictability**: Definitions of timing and metrics are applied to assess delays with respect to planning, average delays, spread in delays, maximum delays, etc.. (KPI_PRED_VARIATION).
- **Sector load**: Definition of workload (for global assessment and total workload on airspace volumes) are formulated and used to determine and to measure the load on sectors, and their relevance. The relationship have to be monitored and assessed between forecast predicted capacity in terms of acceptable workload and the simulation determined workload due to traffic load conditions and traffic complexity. Measured data can be used to assess an appropriate understanding of the balance between demand and capacity as well as the appropriate functioning of the modelling. (KPI_CAP_WORKLOAD, KPI_CAP_ELEMENTARY, KPI_CAP_SCATTERING).
- **Network load**: The number and percentage of sectors and airports per hour that reach their declared capacity, is used as a measure to show the network load. (KPI_CAP_OVERALL).

7.2.4 Cost-benefits Issues

(127) The Cost Benefit Analysis to be performed in the framework of the ERASMUS project is designed as to be carried out by taking two main steps:

- Estimate the main potential BENEFITS to be considered in the Cost Benefit Analysis report (D4.4):
- Estimate the main implementation COSTS to be considered in the Cost Benefit Analysis report (D4.4).

(128) Estimating the main potential BENEFITS to be considered in the Cost Benefit Analysis report (D4.4) aims at analysing Results provided by Simulation exercises (FTS/RTS):

- Capacity Issue
- Safety Issue
- Cost-Effectiveness Issue
- Flight Efficiency Issue
- Punctuality and Predictability Issue

(129) Estimate the main implementation COSTS to be considered in the Cost Benefit Analysis report (D4.4) aims at:

- Identifying relevant constraints (Operational and Technical) raising from putting the designed applications into operational implementation:
  - Meteorological data Processing
  - Updating needed for the FMS Capabilities
  - Updating needed for the En-Route ATC Ground System (SDP, FDP, TP, CDF and CRF
  - Data Link Application
- Identifying the main STAKEHOLDERS involved in the loop which have to sustain these implementation costs:
  - Gather ANSP / Airport / Airline / Manufacturer data on costs
- Identifying some order of magnitude about the implementation costs (CATM, SESAR sources).

(130) Following Tables, provide some examples of indicators to be measured in order to quantify Costs and Benefits for the two major stakeholders foreseen as to be impacted from the implementation of the ERASMUS Concept of Operations and its Working Methods**.**

Indicator	Definition
Costs associated to the implementation of the ERASMUS Concept and Tool (ANSPs)	
Infrastructure	Total infrastructure costs. Working Life ~ 30 years. • Plot urbanization and access construction: (Access roads, Walls, Urbanization, Service roads, etc.)

	• Building: • Auxiliary infrastructure systems: (Energy, Fire fighting, Acclimatisation, Supervision systems, Security, Fuel, etc.) • Operational adaptation of the building: (Furniture, Phone systems, Bar equipment/Kitchen, etc.)
Computer systems	Total computer equipment costs. Working Life ~ 4 years. • Communication. • Automation. • Etc.
Non Computer systems	Total no computer equipment costs. Working Life ~ 12 years. Navigation. Surveillance. Etc.
Staff Costs	TBA

Table 7-1 ERASMUS – ANSPs Costs

Indicator	Definition
Costs associated to the implementation of the ERASMUS Concept and Tool (Airlines)	
Ground Equipments	Total infrastructure costs to achieve operative concepts of the ATM investment made by de ANSP. Working Life ~ 30 years
Airborne Equipments: Retrofit	Total cost of the airborne equipment retro fit
Airborne Equipments: Forwardf fit	Total cost of the airborne equipment forward fit.

Table 7-2 ERASMUS – Airlines Costs

Indicator	Definition
Benefits associated to the implementation of the ERASMUS Concept and Tool (ANSPs)	
Staff Cost Savings	Annual saving of staff costs when the project is implemented with regard to the Baseline
Other Cost Savings:	SECURITY: Time series of savings in payments of indemnifications, assurances, isolations, etc. ENVIRONMENT. Time series of saving payment antipollution measures, etc.
Service Unit Cost Savings	TBA

Table 7-3 ERASMUS – Airlines Costs

Indicator	Definition
Benefits associated to the implementation of the ERASMUS Concept and Tool (Airlines)	
Fuel Saving **Flight Time Saving**	Annual saving in the inefficiency of the system when the project is implemented with regard to the Baseline. • Route geometry efficiency • Flight level efficiency • Fuel efficiency
En-Route Charges Decrease	TBA

Table 7-4 ERASMUS – Airlines Costs

7.2.5 Safety Issues

(131) According to the Safety Methodology described in the ERASMUS D4.4 and summarised in the sub section 6.5 of this document, the Safety Assessment tailored for the ERASMUS Operational Concept will profit by a Real Time Simulations exercises. A set of Safety Indicators, to be measured during the aforementioned RTS session, has been identified and reported in the following table 5-1. The whole set of indicators is split in two main categories: qualitative (QL) and quantitative (QN).

Indicator	Definition	Type	Associated Metric & collect method
Safety of the ERASMUS Concept and Tool			
Decrease of the conflict hazard	Ability for the “system” to resolve conflict	QN	Percentage of conflict resolved.
Traffic Complexity - Conflict Exposure time	Ability for the TC to analyse and manage the conflict situation	QN	Time between ATCO intervention and conflict time.
Traffic Complexity	Ability for the TC to analyse and manage the conflict situation	QN	Number of ATCO tactical intervention.
Hazard effects on Separation	The occurrence of an Hazard (system/procedure/human failure) could induce separation infringements between aircraft. The type (vertical/horizontal) and margins of this potential loss of separation have to be observed.	QN	Number and type of separation infringements. Average of the a/c separation (degradation). Minimum separation during infringement (for each separation infringement). Duration of separation infringement (for each separation infringement). => Automatic logging.
Perceived level of Safety	It indicates the perceived ATCOs ability of keeping the provided service at an appropriate level of safety.	QL	Debriefing sessions, interviews with involved ATCOs.
Perceived recovery ability	It indicates the perceived Pilot and ATCOs ability of solving and recovering from an hazardous situation.	QL	Debriefing sessions, interviews with involved Pilot and ATCOs.
Perceived detection ability	It indicates the perceived Pilot and ATCOs ability of detecting an hazardous situation.	QL	Debriefing sessions, interviews with involved Pilot and ATCOs.

Table 7-5 Safety Indicators

7.2.6 Security Issues

(132) Each identified risk is classified from severity (impact) and likelihood points of view.

7.2.6.1 Severity classification

(133) The severity is differentiated from availability, authentication/integrity and confidentiality points of view in levels none, low, medium and high. Here "none" means that loss of the service would have no practical adverse effect on operations.

(134) Examples of impacts that would be categorized as "none" include:

- Aircraft operation: No degradation in mission capability;

- Assets: No maintenance action, scheduled or unscheduled, required for airline assets;
- Financial: Negligible financial loss;
- Human: No discernable negative effect on passengers;
- Public perception: No negative effect on attitude of passengers in airline services.

(135) Here "low" means that loss of the service would have only a limited adverse effect on operations. Examples of impacts that would be categorized as "low" impact include:

- Aircraft operation: Minor degradation in mission capability to an extent and duration that an airline is still able to perform its primary functions, but with reduced effectiveness (e.g. increased crew workload).
- Assets: Minor damage to airline assets;
- Financial: Minor financial loss;
- Human: Discomfort to passengers;
- Public perception: Distrust of some passengers in airline services.

(136) "Medium" means that loss of the service could have a serious adverse effect on operations. Examples of impacts that would be categorized as "medium" impact include:

- Aircraft operation: Degradation in mission capability to an extent and duration that an airline is still able to perform its primary functions, but with noticeably reduced effectiveness (e.g. heavy stress on crew or flight delays).
- Assets: Significant damage to airline assets;
- Financial: Significant financial loss;
- Human: Limited physical harm to individuals;
- Public perception: Serious distrust of some passengers in air traffic, disclosure of confidential airline operational data.

(137) "High" means that loss of the service could have a severe or catastrophic effect on operations. Examples of impacts that would be categorized as "high" impact include:

- Aircraft operation: Serious degradation in or loss of mission capability so that an airline is not able to perform one or more of its primary functions for a period of time – for example flight interrupt or fleet re-route.
- Assets: Major damage to airline assets;
- Financial: Major financial loss;
- Human: Serious or catastrophic physical harm to individuals;
- Public perception: Total loss of confidence in air traffic by passengers, disclosure of security information.

7.2.6.2 Likelihood classification

(138) **The likelihood is classified as unlikely, likely and highly likely.** For threats (external sources of risks) the level of the likelihood – the potentiality is estimated by judgment of natural exposure, impunity of the aggressor and realisation easiness.

7.2.6.3 Indicators and Metrics

(139) From security point of view the indicator and metric is that all identified risks are either acceptable or unacceptable but with recommended solution (e.g. a proposition of methods of risk's mitigation).

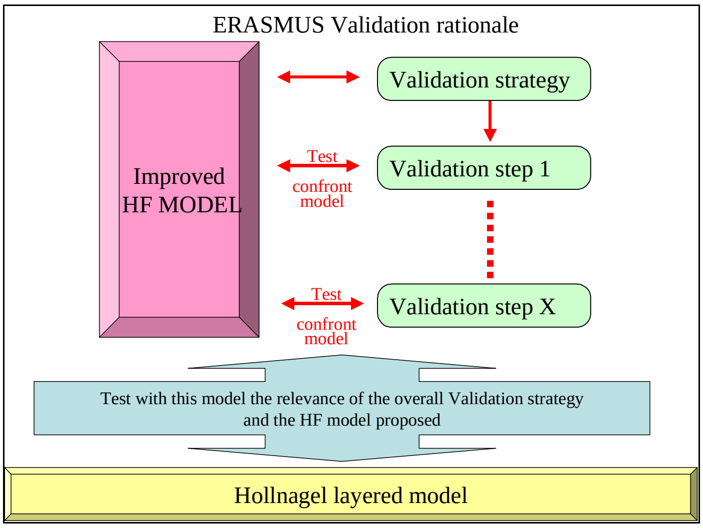
7.2.7 Environmental Issues

(140) Main environmental issues for the En Route phase consist of:

- **Environmental load**: Metrics addressed, to determine distance flown and fuel consumption, are used to assess efficiency as well as emissions (environmental sustainability). Also, flight paths, flown at lower levels during approach and departure, are used to address the noise load on the environment. (KPI_EFF_FUEL_OCC, KPI_EFF_FUEL_SEV, KPI_ENV_OVERALLFUEL);
- **noise impacts** limited to sonic boom (not addressed);
- and mainly **atmospheric impacts** that encompass gaseous emissions (CO_2, NO_x, H_2O, etc.) and other secondary effect such as contrail triggered cirrus (not addressed).

7.3 Initial validation needs

(141) The ERASMUS validation process consists in developing a series of validation exercises supported by relevant parts of theoretical human-factor models. Each validation exercise should allow to refine the model. The Hollnagel model will be used to test the ERASMUS consolidated HF model.



(142) ERASMUS human-factor model will aim at describing the joint system – controller – pilot interaction while trying to represent the dependencies between the elements considered in the cognitive model (i.e. attention resources, doubt management, confidence, workload, etc.).

(143) It will also aim at describing the link between the model and the system performance in order to make explicit the logic of the measurements expected to be carried out along the validation steps.

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8 Setting the strategy

(144) The E-OCVM provides a life-cycle view of the validation process. The system engineering process (from concept evaluation through development and into operation) runs in parallel with this validation process. Both are iterative in nature, and each must feed the other. The validation conclusions must drive system-engineering decisions and the validation must evaluate the system-engineering results. This mutual interweaving is depicted in Figure 6. Both begin with the same embryo concepts. The system engineering leads to the operational system, and the validation leads to the case that supports its operation. Not shown (for simplicity) are the precursor concepts, designs and prototypes on the one side, and the corresponding evolving cases on the other.

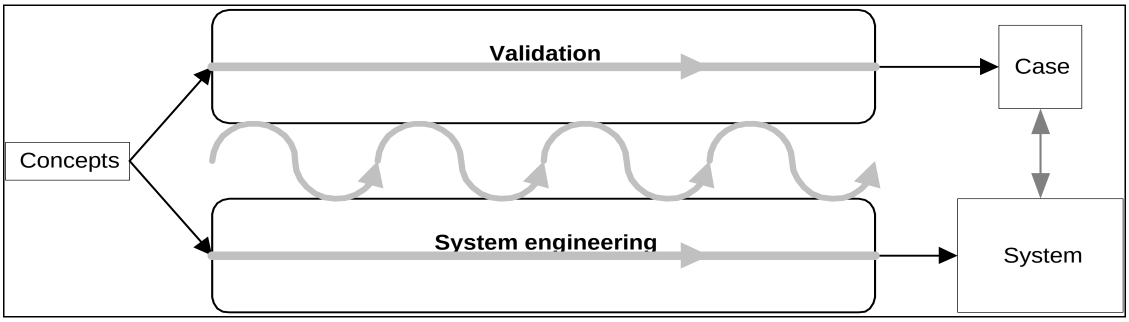

Figure 6: Complementary life-cycle processes

(145) Within this broad framework of interdependent validation and system engineering, the other specialist disciplines must fit. Most disciplines will contribute to both system engineering and validation. For example, HF activities will help to optimise the system design, and HF analyses will contribute to assessments of risk and cost.

8.1 Programme validation process

(146) The tables below summarise the programme validation processes. Each table shows how an ERASMUS issue is addressed through validation methods and exercises. It also shows how each validation exercise can contribute to the programme supporting cases.

(147) ERASMUS issues addressed are:

- Operational and Human Factors
- Technical issues
- Efficiency, capacity and predictability;
- Cost benefits.

(148) The validation process concerns the Baseline scenario (2007) and the 2020 scenario:

- The Baseline scenario corresponds to the expe-4 Real-Time simulation
- The 2020 scenario corresponds to the expe-5 Real-Time simulation

(149) Preliminary and exploratory experimentations are necessary to prepare the expe-4 and the expe-5. It concerns the expe-1, expe-2, expe-3, expe-X.

8.1.1 Operational and Human Factors Issues

Reference	Research Questions	Indicator	Method	Work Package	Validation Exercise	Planning	Resources
R1	Are there doubt situations?	Risk perception Safety feeling Difficulty feeling	RT-Simulation	WP4.3	Expe-2	April'2007	SDER EUR
R2	Does it will save mental resources ? Does it allow to improve the human performance ?	Nb a/c considered / Nb a/c not considered whereas they should be	RT-Simulation	WP4.3	Expe-3 Expe-X	May'2007 March'2008	SDER EUR LIU
R3	Does the improvement of the conflict information quality will conserve mental resources ?	Risk perception Safety feeling Difficulty feeling	RT-Simulation	WP4.3	Expe-5	Oct'2008	All
R4	Does the reduction of conflict release the attention processes ? Does it will save mental resources ? Does it allow to improve the human performance ?	Nb a/c considered / Nb a/c not considered whereas they should be	RT-Simulation	WP4.3	Expe-5	Oct'2008	All
R5	Is ATCO disturbed by modification of a/c trajectories?	Statement of speed modification perception	RT-Simulation	WP4.3	Expe-1 Expe-3	Nov'2006 May'2007	SDER
R6	Do modifications generate added communications between ATCO & pilot?	Nb of ATCO – Pilot communications	RT-Simulation	WP4.3	Expe-X	March'2008	SDER EUR
R7	Do modifications create different understanding from ATCO & pilot?	Content of ATCO – Pilot communications	RT-Simulation	WP4.3	Expe-5	June'2008 Oct'2008	All
R8	Are there interferences between TS strategy & operators' strategy?	Nb of technical system actions interrupted	RT-Simulation	WP4.3	Expe-4 Expe-5	June'2008 Oct'2008	All
R9	Is the HMI provide an efficient environment for the operators ?	???	RT-Simulation	WP4.3	Expe-5	Oct'2008	All
R10	Is it acceptable for pilot to receive an order coming from a machine instead of an ATCO?	Rate and reasons of technical system actions carrying out by the pilot	HF case	WP4.3	Expe-4 Expe-5	June'2008 Oct'2008	All
R11	Does the integration of ERASMUS in the cockpit overload the pilot?	Verbalisation (/workload)	RT-Simulation	WP4.3	Expe-4 Expe-5	June'2008 Oct'2008	All
R12	How to address the responsibility transfer and the role change issues ?		Paper Study	WP2.4		Sept'2008	EUR

IMPORTANT : The ERASMUS concept is built on series of hypothesis that required to be validated step by step before to jump in a complete Air/Ground Human/machine experimentation. In consequence, a set of 4 Human In The Loop experimentations have been realised (expe-1, expe-2, expe-3, expe-X) in order to prepare the final Baseline scenario HITL experimentation (expe-4) and the 2020 scenario HITL (expe-5).

8.1.2 Technical Issues

Validation exercises	Method	Tools	Data	Work Package	Schedule	Resources	Link to research questions
Error Sources study	Paper study	Not applicable	Document sources	WP1.1	Oct.2006 – March 2007	HON	R13 , R14 , R15
Influence of errors wind on predicted airborne trajectory	Modelling simulation	Honeywell HSS	Track data derived from simulated flights	WP1.1	Oct.2006 – March 2007	HON	R13 , R14 , R15
Influence of wrong gross weight entered into FMS on predicted airborne trajectory	Modelling simulation	Honeywell HSS	Track data derived from simulated flights	WP1.1	Oct.2006 – March 2007	HON	R13 , R14 , R15
Influence of vertical wind on predicted airborne trajectory	Modelling simulation	Honeywell HSS	Track data derived from simulated flights	WP1.1	Oct.2006 – March 2007	HON	R13 , R14 , R15
Influence of navigation errors on predicted airborne trajectory.	Modelling simulation	Honeywell HSS	Track data derived from simulated flights	WP1.1	Oct.2006 – March 2007	HON	R13 , R14 , R15
Influence on wind on RTA contracts	Modelling simulation	Honeywell HSS	Track data derived from simulated flights	WP1.1	Oct.2006 – March 2007	HON	R31
Influence of wind errors on trajectory predicted by the ground system	Modelling simulation	ETH FTS	Track data derived from simulated flights	WP1.2.2	March 2007 – July 2008	ETH	R22, R23
Influence of incorrect AC state data (e.g., gross weight) entered into the GTP on the trajectory predicted by the ground system	Modelling simulation	ETH FTS	Track data derived from simulated flights	WP1.2.2	March 2007 – July 2008	ETH	R19, R20
Influence of vertical wind on the trajectory predicted by the ground system	Modelling simulation	ETH FTS	Track data derived from simulated flights	WP1.2.2	March 2007 – July 2008	ETH	R22, R23
Data-link technologies study	Paper study	Not applicable	Document sources	WP1.2.2	Oct.2006 – Nov. 2008	HON, EEC	R16 , R17 , R18 , R19 , R20 , R39 , R40 , R41
Functional test of simulated data-link technologies	Modelling simulation	SDER platform	Track data derived from simulated flights and recordings	WP1.3.3	Sept 2007 – July 2008	HON, SDER	R37
Functional test of simulated Conflict Resolution manoeuvres.	Modelling simulation	SDER platform	Track data derived from simulated flights	WP1.3.3	Sept 2007 – July 2008	HON, SDER, ETH	R40, R41, R32, R24, R30, R31,

Validation exercises	Method	Tools	Data	Work Package	Schedule	Resources	Link to research questions
			and recordings				R33, R34, R36
Influence of transmission delays	Modelling real/fast-time simulation	SDER platform	Track data derived from simulated flights and recordings	WP1.3.3	Sept 2007 – July 2008	HON, SDER	R29, R30
Influence of transmission periodicity	Modelling real/fast-time simulation	Honeywell HSS, SDER platform	Track data derived from simulated flights and recordings	WP1.3.3	Sept 2007 – July 2008	HON, SDER	R29, R30
Flight tests to compare Airborne TP and ground TP spatially and timely	Modelling real/fast-time simulation	Honeywell HSS, SDER platform, ETH FTS	Track data derived from simulated flights and recordings	WP1.2.2	May 2007 – Nov 2008	HON, ETH, SDER	R19, R20, R21, R22, R25
Airline recommended speed changes study	Paper study	Not applicable	Document sources	WP1.2.2	May 2007 – Nov 2008	HON	R28
Airborne equipment requirements study	Paper study	Not applicable	Document sources	WP1.2.2	May 2007 – Nov 2008	HON	R18, R32, R37, R35
Range of RTA errors	Modelling real/fast-time simulation	Honeywell HSS, SDER platform, ETH FTS	Track data derived from simulated flights and recordings	WP1.3.3	Sept 2007 – July 2008	HON SDER ETH	R28
RNP requirements	Modelling real/fast-time simulation	Honeywell HSS, SDER platform, ETH FTS	Track data derived from simulated flights and recordings	WP1.3.3	Sept 2007 – July 2008	HON SDER ETH	R31

8.1.3 Efficiency, Capacity and Predictability Issues

Ref	Research Questions	Indicator	Method/tool	Work Package	Validation Exercise	Planning	Resources
R50	Sector Load	KPI_CAP_WORKLOAD KPI_CAP_ELEMENTARY KPI_CAP_SCATTERING	RT-Simulation	WP4.4	Baseline scenario 2020 scenario	Sept'2008 Feb'09	SDER EUR
R51	Traffic Throughput	KPI_CAP_THROUGHPUT	COSAAC	WP4.4	Baseline scenario 2020 scenario	Sept'2008 Dec'2008	SDER EUR
R52	Network Load	KPI_CAP_OVERALL	COSAAC	WP4.4	Baseline scenario 2020 scenario	Sept'2008 Feb'09	SDER EUR
R53	Flight efficiency and environmental load	KPI_EFF_FUEL_OCC KPI_EFF_FUEL_SEV KPI_ENV_OVERALLFUEL	CATS	WP4.4	Baseline scenario 2020 scenario	Sept'2008 Feb'09	SDER EUR
R54	Traffic Delay	KPI_EFF_DURATION_OCC KPI_EFF_DURATION_SEV	CATS	WP4.4	Baseline scenario 2020 scenario	Sept'2008 Feb'09	SDER EUR
R55	Flight Predictability	KPI_PRED_VARIATION	CATS	WP4.4	Baseline scenario 2020 scenario	Sept'2008 Feb'09	SDER EUR

8.1.4 Cost-benefits Issues

(150) The economic viability of a concept of operations is constrained by the benefits and costs it incurs, the tie it takes to develop and implement, as well as other limited resources, and the available opportunities in the economy and elsewhere.

(151) The main goal of the proposed economic analysis is to understand economic phenomena associated to the implementation of the concept of operations.

(152) The analysis proposed is based on three activities

- Cost identification (Qualitative Assessment)
- Quantitative benefit identification
- Summary of costs and benefits

(153) To support this activity and ensure a common understanding and dissemination of the foreseen work, the project will perform the following activities

- Produce an Anticipated Benefits document ERASMUS (D2.3), that will detail, in a qualitative way, the main costs to be sustained and the most appreciable benefits that could be associated to the implementation of the ERASMUS Concept of Operations.
- Obtain cost analysis requirements description, that will provide a standard format for the documentation and results
- Develop rules and assumptions to communicate the context and environment within which the analysis is being developed
- Select a cost estimating methodology on the basis of available information and on the concept of operations maturity
- Translate the qualitative estimations of Costs and Benefits into tangible figures (ERASMUS D4.4) by:
    - Estimating and quantifying a set of potential BENEFITS achievable by adopting the ERASMUS Operational Concept
    - Identifying and quantifying main COSTS deriving from the translation of the ERASMUS Operational Concept into a “real system + working method”
    - Appling a “comparative analysis” between the individuated BENEFITS and COSTS

(154) The Cost Benefits Analysis to be performed in the context of ERASMUS is split in two main steps. The first one, taken largely in advance compared to the other, consists of a qualitative estimation of costs and benefits associated to the adoption, into the operational environment, of the ERASMUS Operational Concept Element and the associated working methods. The output of this activity are summarised inside the ERASMUS D2.3 Anticipated Benefits. These preliminary results have to be considered as the main input for a deeper an more exhaustive economical investigation to be done in the framework of the WP 4.4. At that stage, the data provided by the qualitative analysis have to be translated, as much as possible, in figures in order to make it clear that ERASMUS is, among others, a valid solution from the economic point of view.

Ref	Research Questions	Indicator	Method/tool	WP	Validation Exercise	Planning	Who
R60	Cost-benefit impact (ref. chapter 8.2.4)	Ref chapter 8.2.4	Cost-benefit assessment	4.4	Baseline scenario 2020 scenario	Sept'2008 Feb'09	SDER EUR SICTA HON

8.1.5 Safety Issues

(155) A main step to be taken in order to demonstrate that the ERASMUS concept and its associated modus operandi guarantee an adequate Target Level of Safety is to perform a complete Safety Assessment. In the ERASMUS safety strategy the Safety Methodology SAM (developed by EUROCONTROL) is considered as the main tool to analyse the ERASMUS Concept of Operations from the Safety point of view. It is articulating 3 steps: the Functional Hazards Analysis (FHA), the Preliminary Safety System Assessment (PSSA) and the System Safety Assessment (SSA). As already written above, the current ERASMUS maturity just allows to focus on the hazards analysis providing the list of hazards, their operational effects and the severity classification. However that would put the light on safety constraints to assess the feasibility of the operational concept.

(156) Furthermore, Safety dedicated Real Time Simulations (ERASMUS RTS IV) with controllers using the proposed ERASMUS tools and procedures is planned. Prior to these simulations, the Safety Assessment should have identified important hazards and causal factors.

(157) The aim is to get feed back from RTS using safety observation and debriefing/interviews (Qualitative Indicators) and system logs to make objective measurements (Quantitative Indicators). Two main categories of Scenarios should be considered and jointly used:

1. Nominal situation Sessions;
2. Non-Nominal Sessions (Injection of failure).

(158) The experience that ATCOs gained with the concept in RTS, will be used via de-briefing & brainstorming shortly after simulations. Measures like workload or situational awareness might provide useful indication on potential for hazards occurrence and on capability to recover from them.

(159) Ad-hoc questionnaires and some debriefing tools will be prepared prior to RTS. According to which are the main Hazards identified in the previous step, failure scenarios will be defined for Non-Nominal Sessions.

(160) The Safety results from the RTS will further feed into the full HAZID and ultimately be stored in the Hazard Log (Cycle 0 final version).

(161) Data from the real time simulations will need to be fed back into updates of the Safety Assessment.

(162) The Safety Assessment for the ERASMUS project is part of the WP4.4 and the outcome of this activity will be mainly reported into the D4.4. The following table 7-1 shows which are the main steps, related to the Safety Assessment, are going to be taken in the context of the ERASMUS Project.

Safety Assessment activities	Description
1. Scoping HAZID 1	An initial Hazard Identification will perform a preliminary identification of any hazard relevant for the OCE as a generic concept, while highlighting the needs for further safety investigation.
2. Scoping HAZID 2 (RTS Safety observation)	The aim is to revisit and complement the previously performed Hazard Identification accounting for the generic OCE and to get the pilot and RNAV specialist feed-back with respect to those hazards. This activity will be carried out exploiting the experience of Pilots involved in RTS. The Pilots will contribute with their experience to refine the Hazards list (or to identify new hazards) and their consequences on operations and safety, in order to obtain a reasonably complete hazards analysis. Additionally, a basic classification of hazards and errors/failures will be

	performed according to experts' judgement on the consequences severity combined, when possible, with level of occurrence frequency.
3. Scoping HAZID 3 (Brainstorming)	This step will allow consolidating the Hazard analysis exploiting the experience that the ATCOs gained with the concept in RTS. It will get feedback on the operational impact of most credible Hazards, even not in terms of their likelihood of occurrence.
4. Full HAZID	This Hazard Identification has the scope of tackling the operational effects of failures, accounting for existing mitigation to prevent hazard occurrence, or barriers that minimize the hazard effect.
5. Integration of RTS Results into the Safety Assessment Conclusions	Data from the real time simulations will need to be fed back into updates of the Safety Assessment.

Table 8-1 ERASMUS: Main Safety Activities

Ref	Research Questions	Indicator	Method/tool	WP	Validation Exercise	Planning	Who
R70	Safety impact	KPI_SAF_PROPENSITY KPI_SAF_SEPLOSSES-OCC KPI_SAF_SEPLOSSES-SEV KPI_SAF_DENSITY KPI_SAF_OVERLOADS	RTS+ Questionnaires and Debriefing sessions RTS Data Post processing Safety Case HAZID	4.4	Baseline scenario 2020 scenario	Sept'2008 Feb'09	SDER EUR SICTA HON LIU

8.1.6 Security Issues

8.1.6.1 System description and characterization, Operational services

(163) In assessing risks for a system, the first step is to define the scope of the effort. In this step, the boundaries of the system are identified, along with the resources and the information that constitute the system. Characterizing a system establishes the scope of the risk assessment effort, delineates the operational authorization (or accreditation) boundaries, and provides information (e.g., hardware, software, system connectivity, and responsible division or support personnel) essential to defining the risk.

(164) Especially it is appropriated to concern with operational services which are related to ERASMUS so which are participated in important data transmission (e.g. Automatic Dependent Surveillance Broadcast – ADS-B, Automatic Dependent Surveillance Contract – ADS-C, The Controller Pilot Data Link Communication – CPDLC, The ATC Communications Management – ACM, Aeronautical Telecommunication Network - ATN…).

8.1.6.2 Description of input and output data

(165) It is necessary to identify and describe data which are related to actions associated with ERASMUS topic – the trajectory negotiation (i.e. Aircraft state data, Trajectory intent data, Atmospheric characteristic data, Trajectory or aircraft constraints data, Control data).

8.1.6.3 Security categorization – Impact factor

(166) The data are classified in this step. The categorization is made from point of view Availability of data, Authenticity and Integrity of data and Confidentiality of data. Each data is evaluated of each point of view as None, Low, Medium or High where values "None" – "High" are answers to a question "what is the impact when the availability / authenticity / integrity / confidentiality of the data/service is lost?".

(167) "Availability" means ensuring authorized users have access to information and associated assets when required (protection against disruption of access to, or use of information). „Authenticity" means verifying the identity of an user, process, or device, often as a prerequisite to allowing access to resources in a system, ensuring the obtained information was sent by an authorised user.

(168) „Integrity" means safeguarding the accuracy and completeness of information and processing methods. „Authenticity / Integrity" together means protection against unauthorized modification or destruction of information.

(169) „Confidentiality" means ensuring that information is accessible only to those authorized to have access (protection against unauthorized disclosure of information).

(170) "None" means that loss of the service would have no practical adverse effect on operations, "Low" means that loss of the service would have only a limited adverse effect on operations, "Medium" means that loss of the service could have a serious adverse effect on operations and "High" means that loss of the service could have a severe or catastrophic effect on operations.

8.1.6.4 Physical environment and assumptions

(171) Characteristics of the physical and operational environment in which the system operates will often impact the selection of security controls. Unfortunately it is hard to generalize in this area, and a system-specific assessment must be carried out in order to identify relevant characteristics.

Characteristics of the environment in which the system will operate that can affect selection of security controls may include:

- Physical characteristics such as:
    - Current physical environment (physical access, premises, office material, telephones, telecopy, etc.);
    - Computers (servers, work stations, data network, etc.);
    - General or specific documentation.
- Non-material characteristics such as:
    - Procedures and processes;
    - Data (files, databases, etc.);
    - Programs (general or specific software).
- Personnel characteristics such as:
    - Essential personnel (skills, power to decide, etc.);
    - Non-essential personnel (domestic help, etc.);
    - Trustable or not trustable personnel.

(172) As a general security principle it is desirable to minimize the system elements that are assumed to be trusted during this process.

8.1.6.5 Assess risk

(173) On the basis of System description and Security categorisation of identified data it is necessary to identify vulnerabilities. “Vulnerability” means an internal source of risk. The main areas of vulnerability of air-ground data communications are:

- Air-ground data communication path (e.g. satellite, VHF, HF);
- Data transfer over service networks (e.g. public communication networks, aircraft networks);
- Physical access to equipment and circuits (e.g., impracticability of achieving physical security at isolated or remote locations).

(174) The second part of this step is the analysis of threats. “Threat” means an external source of risk. Threats’ scenarios are constructed by qualitative approach – by experts’ experiences, etc. and the threats are identified. Examples of potential attacks include:

- Monitoring the transmission medium;
- Modification to the address information or the content of information resulting in untimely, duplicate or non-delivery of messages;
- Jamming or flooding the network or a particular transmission medium;
- Masquerading as a genuine user (e.g., phantom controllers or phantom pilots);
- Replaying an earlier valid message at an inappropriate time;
- Modification to the routing information tables of the network.

(175) The analysis of the threats is made from point of view the Natural exposure (the attractiveness of the targeted asset for the aggressor or the target’s “risky” situation with respect to the environment), the Impunity of the aggressor (this factor depends on the assessment by the aggressor of the likelihood for him to be identified – notion of accountability – and of the sanctions to which he might be subjected) and the Realisation easiness (this factor depends on the required capacity of the aggressor to carry out the attack scenario and on the means which are necessary and which he must command). The result is the Potentiality of the threat.

(176) The Risks are identified by merging of Vulnerabilities and Threats. Risk likelihood (Unlikely/Likely/Highly likely) and Risk severity (Low/Medium/High) are estimated by the Potentiality of the Threat and the Impact of the Vulnerability. The Rate of the Risk (Acceptable, Unacceptable) is obtained by combination of the Risk likelihood and Risk severity. The combination severity/likelihood “High/Likely”, “High/Highly likely”, “Medium/Likely” and “Medium/Highly likely” are Unacceptable and Security objectives shall be defined to reduce risk to an acceptable level. Other combinations are acceptable.

8.1.6.6 Security objectives

(177) On the basis of Physical environment and assumptions and Assess risk it is possible to identify Security objectives. Security objectives are high-level goals that influence the selection of security controls.

(178) The „ARINC Project paper 811“ suggests 14 objectives that have been identified so far:

- Common Controls Security Objective;
- Cost Security Objective;
- Defense In Depth Security Objective;
- Existing Lifecycle Security Objective;
- Existing Systems Security Objective;
- Flexibility Security Objective;
- Function Security Objective;
- Future Resiliency Objective;
- Minimize Administration Security Objective;
- Mission Accomplishment Security Objective;
- Open Standards Security Objective;
- Public perception Security Objective;
- Safety Security Objective;
- Secure Security Objective.

(179) Firstly we should think of other possibilities of Security objectives, secondly include them into the list of objectives if appropriate, thirdly to choose the ones that are associated with the ERASMUS (delete ARINC 811 Security objectives, if they do not have relevance to ERASMUS) and fourthly to prioritise the objectives with respect to the requirements/goals of the ERASMUS project.

Recommendations of procedural and technical solutions

(180) The purpose of this step is to propose some ways to mitigate the risks with unacceptable level to acceptable level in the frame of identified relevant Security objectives.

(181) The following factors should be considered in recommending controls and alternative solutions to minimize or eliminate identified risks:

- Effectiveness of recommended options (e.g., system compatibility);
- Legislation and regulation;
- Organizational policy;
- Operational impact;
- Safety and reliability.

(182) The control recommendations are the results of the risk assessment process and provide input to the risk mitigation process, during which the recommended procedural and technical security controls are evaluated, prioritised, and implemented.

Ref	Research Questions	Indicator	Method/tool	WP	Validation Exercise	Planning	Who
R80	Security assessment	n/a	Security assessment	4.4	Baseline scenario 2020 scenario	Sept'2008 Feb'09	HON

8.1.7 Environmental Issues

Ref	Research Questions	Indicator	Method/tool	WP	Validation Exercise	Planning	Who
R90	Environmental load	KPI_EFF_FUEL_OCC KPI_EFF_FUEL_SEV KPI_ENV_OVERALLFUEL	CATS + BADA	4.4	Baseline scenario 2020 scenario	Sept'2008 Feb'09	SDER EUR

8.2 Research questions trace-ability

(183) The table below presents the research questions references related to the three ERASMUS applications.

ERASMUS Applications	Research questions references						
	Operational & HF issues	**Technical issues**	**Efficiency, Capacity & Predictability Issues**	**Cost-benefits issues**	**Safety issues**	**Security issues**	**Environmental issues**
Strategic de-conflicting Separation management	R1 **Error! Reference source not found.**R5 R6 R7 R8 R10 R11 **Error! Reference source not found.Error! Reference source not found.**	R16 R17 R18 R19 R20 R23 R28 R29 R30 R31 R32 R33 R34 R36 R37 R38 R39 R40 R41 R13 R14 R21 R22 R24 R25 R26 R27 R42 R43	R50, R51, R52, R53, R54; R55	R60	R70	R80	R90

8.3 Factors that shape the strategy

(184) This section summarises the constraints that ERASMUS project must take into consideration when determining what to develop and evaluate.

8.3.1 Deliverable constraints

Specific deliverable are linked to validation plan output:

WP4.2	Definition of Operational Scenarios	D4.2.1 D4.2.2
WP4.4	Security, Safety, Efficiency, Cost-benefit Assessment	D4.4.1 D4.4.2

8.3.2 Maturity of concepts

(185) The maturity of the concepts to be tested will have a large impact on what sort of validation activities will be possible. The E-OCVM concept maturity model is proposed that shows how the scope of validation activities should be sensitive to the stability of operating procedures and supporting HMI.

(186) Many of the HF concepts that ERASMUS is proposing will be described in various documents and will be integrated along the project lifecycle into the Concept of Operations document. This will tend to reduce the scope of the possible validation activities.

8.3.3 Availability of simulation platform

(187) The main technique to be used in ERASMUS for the concept evaluation is real-time simulation. A large percentage of these simulations will use the platform developed by DTI (CENA). Where a concept requires new software functions to support its operating procedures the availability of that software in a stable state will determine whether the concept can be tested reasonably or not. Thus where simulations are programmed to use novel software functions the objectives will be very restricted until it can be shown that the software is stable and supports the concept in the way expected.

8.3.4 Target date for implementation

(188) ERASMUS is targeted at “being available for pre-implementation of SESAR” from 2020. For any concept validation phase and any application testing to be considered it should be within this timeframe.

8.3.5 Project deadline

(189) The project is planned to last 30 months starting May 2006 but is delayed by 6 months. End date planned on May’2009. All validation steps and experiment to support the strategy should occur in this timeframe.

9 MANAGEMENT INFORMATION

9.1 Resources

9.1.1 Partners

(190) Partners are EUROCONTROL, DTI/DSNA, Honeywell, University of Linkoping, Swiss Federal Institute of Technology, SICTA.

9.1.2 Operational and technical resources

	EUR	DSNA	HON	LIU	ETH	SIC	Total
WP 4	31	22	32	16	3.5	23	127.5

9.2 Validation milestones and deliverables

Project / WP	Description	Resp.	Delivery mm/yy (first release)
WP4.1	D4.1 Validation Plan	EUR	April'2007
WP4.2.	D4.2.1 Definition of the Experimental Plan – Baseline scenario (finale expe-4)	EUR	March'2008
WP4.2.	D4.2.2 Definition of the Experimental Plan – 2020 scenario (finale expe-5)	EUR	Sept'2008
WP1.1	Air trajectory prediction	HON	Apr'2007
WP1.2	Ground trajectory prediction	HON	Nov'2007
WP1.3	Fast-time simulation	HON	Jul'2007
WP4.3	M4.3.1 – expe-4 (baseline scenario)	SDER	June'2008
WP4.3	M4.3.2- expe-5 (2020 scenario)	SDER	Oct'2008
WP4.4	D4.4.1 Security, safety, efficiency and CBA - Baseline scenario	SICTA	Sept'2008
WP4.4	D4.4.2 Security, safety, efficiency and CBA - 2020 scenario	SICTA	Feb'2009
WP4.5	D4.5.1 Result Analysis - Baseline scenario	LIU	Aug'2008
WP4.5	D4.5.2 Result Analysis - 2020 scenario	LIU	Dec'2008
WP4.6	D4.6 Final Report	EUR	March'2009

9.3 Risk and Mitigation

Risk	Mitigation
None	

End of document

Annexes

ANNEX A - Review of existing validation programmes and results

(191) Up to now, one experiment (experiment 1) has been carried out providing some results. Experiment 2 started with initial results from a pre-experimental phase. Experiment 3 is planned with defined objectives. A synthesis of these three experiments objectives and results when appropriate is presented in the chapters below. Case based studies (Safety, HF and Business cases) are also planned as useful data to further integrate in the validation plan.

ANNEX A - 1. Experiment 1

Experiment 1 validation results

(192) Experiment 1 took place at Marseille ACC from the 13th to 24th November 2006. The main objectives of the experiment consisted in studying controller's perception of horizontal speed variation on managed aircraft.

(193) The experimental task for controllers consisted in detecting horizontal speed variations for a traffic that was replayed on the radar image. The traffic development had been partly modified by an automated system which performed speed variations on certain aircraft. The controllers were also asked to detect conflicts as a secondary task corresponding to their usual traffic analysis.

(194) Each ATCO performed the two tasks under two situations: low traffic load and high traffic load.

(195) The main results of the experiment were as it follows:

- the controllers perceived that 34% of the aircraft had their speed automatically modified. Among these aircraft, 8% were actually not modified;
- 64% of speed variations performed by the system were not perceived by the controllers.

(196) The maximum of (correct) speed variation perception was in low traffic load condition with speed reduction of -12% (i.e. 50 to 60 knots speed decrease), and when the speed modification occurred after the integration by the controller (within the managed sector).

(197) The speed variation was better perceived when applied to aircraft in conflict, that is when the controller turns a particular attention to aircraft (speed being not a parameter specifically monitored).

Experiment 1 assessment technique

Data collection method or tool	Objective	Completed
Post run questionnaire	Assess participants' ratings of overall workload.	After a run
Post-Run debriefing	Gather information concerning the participants perceived speed variations, the impact of the ERASMUS actions on workload and situation awareness during the run.	After set of runs
Observation by a operational expert and a HF specialist	Gather information concerning the information expressed by the controllers about their feeling of speed modification, the callsign, the sense of variation, some justifications.	During run
System log	Gather information on the ATM system performance (Nb of instructions,	During run

recording	Duration of resolution loop with a/c)	
Audio recording	Gather information to be used for post analysis of efficiency, strategy, human errors…	During run

Experiment 1 technical constraints

(198) The main technical limit was that ERASMUS algorithm was not implemented: an operational expert simulated ERASMUS action on some aircraft (Wizard of Oz technique).

(199) Otherwise, in order to obtain a measurable and visible effect, the range of speed variations was, on purpose, not realistic: it consisted in a speed reduction of -12% whereas ERASMUS actions should apply speed variations of -6% to +3%.

ANNEX A - 2. Experiment 2

Experiment 2 validation results

(200) The purpose of experiment 2 was to determine the effective action area of ERASMUS (i.e. "ideal" traffic configurations) and the relevant complexity criteria in the controller's perspective.

(201) The first phase of experiment 2 (pre-experiment) took place at Marseille ACC from the 31st January to the 1st February 2007. The main objectives of the pre-experiment consisted in qualitatively defining the safety feeling, the difficulty feeling and workload feeling.

(202) The controllers defined the workload feeling as resulting from the addition of the safety and difficulty feeling. The safety feeling was defined as depending on self confidence, group pressure and personal state. The difficulty feeling was described regarding the problems configuration, the solutions and the room for manoeuvre.

(203) The initial main results of the pre-experiment showed that the controllers have difficulty to dissociate doubt on the conflict reality from doubt on the solution to carry out. The doubt removal process is a traffic management strategy which is considered as consuming resources and being marginally used and in case of low workload situations. On the contrary, the immediate traffic pre-categorisation is used as resources self management.

(204) The second phase of experiment 2 took place at Toulouse from the 16th January to the 20th April 2007. Its main objective was to verify whether the traffic distribution (according to the level of perceived conflicts) was influencing the affective representation of the situation (in terms of safety, difficulty and workload feelings). The controllers were placed in front of several traffic scenarios but were not handling the traffic. They had questionnaires to fulfil and they participated to debriefings. The results confirm the pre-experiment results findings.

Experiment 2 assessment technique

Data collection method or tool	Objective	Completed
Phase 1: Pre-Experiment 2		
Thematic collective interview	Clinic method. (4 to 6 participants by session - 4 sessions).	
Phase 2: Experiment 2		
1) Short scenarios		
Feelings Form	3 auto assessment gradual scales of the feelings on the 3 dimensions (SF,DF;WF)	After a short scenario

	1 multiple choices question regarding the criteria which have determined the auto assessment of the 3 feelings dimensions. 1 question of judgement on the counting of the a/c pairs according to their belonging to one of the 3 bars (conflict, doubt, no conflict)	
General post-session debriefing	Further information on mini debriefing and more analytic or explicative comments on the feelings regarding the different traffic configurations (about 3/4 H or 1H, on all displayed short scenarios)	After set of short scenarios
2) Long scenarios		
Crossed "mini-debriefing" + Audio recording	Confrontation of 2 controllers points of view using screenshot of the traffic situation when pause to sustain the comments + feelings forms (Temporally limited: 10 minutes)	Follow controller pause request of the scenario for comments
Traffic situation screenshot (Printed in real time)	Further processed as data (i.e. not only debriefing support)	When pause in the scenario
Feelings forms	3 auto assessment gradual scales of the feelings on the 3 dimensions (SF,DF;WF) 1 multiple choices question regarding the criteria which have determined the auto assessment of the 3 feelings dimensions. 1 question of judgement on the counting of the a/c pairs according to their belonging to one of the 3 bars (conflict, doubt, no conflict)	Follow a controller pause request of the scenario for comments
General post-session debriefing	Further information on mini debriefing and more analytic or explicative comments on the feelings regarding the different traffic configurations (about 3/4 H or 1H, on all displayed short scenarios)	After set of short scenarios
HMI log	Gather information on the traffic situation.	During run
Audio recording	Spontaneous comments during long scenarios visualisation	During long scenarios

Experiment 2 technical constraints

(205) The main technical limit is the number of traffic configurations due to the necessity to put in context the scenarios (transition phases limit the exercise time and the number of traffic configurations that can be tested).

ANNEX A - 3. Experiment 3

Experiment 3 validation results

(206) Experiment 3 took place at Marseille ACC in May 2007.

(207) This experiment was set up to:

- Validate the thresholds identified in experiment 2 between the different buckets;
- Gain insight on controllers practices to deal with conflict management and doubt management;
- Test different configurations and different traffic samples;
- Quantify the gain in controller performances of the Strategic De-conflicting application.

(208) It aimed at testing the gain in resources provided by ERASMUS and at better defining the content and criterion of feelings elements introduced to qualify the traffic.

(209) It tried to answer the following research questions:

- Are there doubt situation?

- Does the reduction of doubt situation release the attention processes?

(210) The results showed a tendency for ERASMUS to save controllers resources. The gain delivered by ERASMUS did not seem to be in terms of absolute capacity or workload but more in terms of comfort, improvement of service delivered to aircraft and safety merging. The main results were on the improvement of safety critical situation with ERASMUS; reduction of potentially conflicting aircraft, increase separation for doubtful situation. The tendencies shown in the results suggested an effect of the composition of the traffic on the results. This impact was not only in terms of traffic load (number of aircraft) but also in term of traffic repartition. ERASMUS seemed to be efficient at a specific traffic load.

Experiment 3 assessment technique

Data collection method or tool	Objective	Completed
Post run questionnaire	Assess participants' ratings of overall workload and situation awareness across the run (NASA TLX, AIM ratings, SASHA ratings).	After a run
Post-Run debriefing	Assess participants' ratings of the impact of the ERASMUS actions on workload and situation awareness during that run.	After set of runs
Observation by an operational expert	Gather information concerning the participants strategy and efficiency; discuss the concepts, procedures, and HMI.	During run
Observation by a human factors specialist	Gather information about stress, workload, confidence, etc.	During run
Data from monitoring equipment Eye-tracker	Gather information of the visual strategy mainly for SA evaluation (Gaze analysis and pupil diameter).	During run
Instantaneous self assessment (workload)	Subjective and intrusive tool used to evaluate the instantaneous perceived workload of the participant (ISA box).	During run
Situational Awareness Assessment	Scenario temporarily frozen and hidden from view while asking a series of questions concerning the location of entities within the display (use of Situation Awareness Global Assessment Technique - SAGAT)	During run
System log recording	Gather information on the ATM system performance (Nb of instructions, Duration of resolution loop with a/c)	During run
Audio recording	*Gather information to be used for post analysis of efficiency, strategy, human errors…*	*During run*

Experiment 3 technical constraints

(211) Some technical constraints have been identified:

- The number of control working positions: there is only one radar screen for the tactical controller. An operational expert will play the role of the planning controller to integrate the aircraft and manage the coordination. The impact of the subliminal control on the PC will be assessed later.
- The algorithm efficiency and robustness: the impact of high traffic levels and of dynamic actions of controllers has not been tested yet. This constraint is taken into account in the validation strategy.

ANNEX A - 4. Experiment X

Experiment X validation results

(212) Initially, this Experimentation X was not planned but considering the results of experimentation 3 (ran in 2007), decision was made to run new simulation to refined/review theses results. Experiment X was carried out over two weeks in February and March 2008 at Toulouse with controllers from Aix ACC.

(213) This experiment was set up to:

- Further investigate the Expe-3 tendencies observed;
- Demonstrate the shift from comfort to capacity (i.e prove that capacity is increased);
- Improve the experimental protocol (i.e more rigorous);
- Set up a smaller within-subjects design to ensure of the independent variables can measured;
- Minimise the breaking of ERASMUS actions.

(214) The preliminary results seem to confirm the potential of ERASMUS shown in Experiment 3. The low traffic levels induce situations where controllers are more in a monitoring role and they are more likely to observe the ERASMUS actions. Still these actions seem not to disturb them, moreover the controllers feel comfortable to have a support for conflict resolution (i.e: some aircraft they identified as requiring an action ended with ERASMUS with larger separation and had just to be monitored). The controllers raised the concern of over trust in ERAMUS (i.e. potential tendency to believe it will solve all the conflict).

Experiment X assessment technique

Data collection method or tool	Objective	Completed
Post run questionnaire	Assess participants' ratings of overall workload and situation awareness across the run (NASA TLX, AIM ratings, SASHA ratings).	After a run
Post-Run debriefing	Assess participants' ratings of the impact of the ERASMUS actions on workload and situation awareness during that run.	After set of runs
Observation by an operational expert	Gather information concerning the participants strategy and efficiency; discuss the concepts, procedures, and HMI.	During run
Observation by a human factors specialist	Gather information about stress, workload, confidence, etc.	During run
Data from monitoring equipment Eye-tracker	Gather information of the visual strategy mainly for SA evaluation (Gaze analysis and pupil diameter).	During run
Instantaneous self assessment (workload)	Subjective and intrusive tool used to evaluate the instantaneous perceived workload of the participant (ISA box).	During run
Situational Awareness Assessment	Scenario temporarily frozen and hidden from view while asking a series of questions concerning the location of entities within the display (use of Situation Awareness Global Assessment Technique - SAGAT)	During run
System log recording	Gather information on the ATM system performance (Nb of instructions, Duration of resolution loop with a/c)	During run
Audio recording	*Gather information to be used for post analysis of efficiency, strategy, human errors…*	*During run*

Experiment X technical constraints

(215) Some technical constraints have been identified:

- The number of control working positions: there is only one radar screen for the tactical controller. An operational expert will play the role of the planning controller to integrate the aircraft and manage the coordination. The impact of the subliminal control on the PC will be assessed later.
- The algorithm efficiency and robustness: the impact of high traffic levels and of dynamic actions of controllers has not been tested yet. This constraint is taken into account in the validation strategy.

ANNEX B - Human Factors Case Assessment

ANNEX B - 1. HF Case Approach

(216) The Human Factors Approach that is to be adopted for the Episode 3 and MTV work programmes is based on the Human Factors Case (EUROCONTROL, 2006). There are 5 main stages that will be used for the integration of Human Factors into the EPISODE 3 / MTV Concept of Operations.

Stage 1. Scoping the Operational Concept "Sub-Element"

(217) Review the initial planning documentation to identify the functions of the system and the required operators tasks:

- Describe the system and functions;
- Describe the operators (and their relationships with other Personnel-Task-Equipment-Environment);
- Identify the operator tasks;
- Identify results from previous relevant studies;
- Allocation of function.

Inputs required	concept documentation (functions)
Outputs	task analysis, allocation of and understanding of the concept

Stage 2. Issue Analysis: Identifying Human Factors Issues

(218) Identify potential risks or enhancements, human constraints and limitations

- Full description of issues;
- Describe the problem or risk associated with the issue (Using the HF Case Pie Approach – System and Human Performance levels);
- Identify the potential consequences of not resolving the issue;
- Potential steps to be taken to resolve the issue status of the corrective actions.

Inputs required	concept definition; functions; task analysis
Outputs	identified human factors issues and prioritisation

Stage 3. Human Factors Action Plan

(219) Based on the task analysis and human factors issue analysis, a human factors action plan will be developed that will include:

- a set of human factors objectives, for example: objectives for meeting required performance levels, reducing errors, minimising or eliminating safety risks, controlling total workload;
- a list of identified human factors issues;
- a list of HF activities to be undertaken;

- Initial requirements to input into the detailed description of roles, responsibilities and working positions are produced at this stage.

Inputs required	task analysis; HF principles; HFIA
Outputs	HF Plan, HF objectives, HF activities, initial HF requirements

Stage 4. Human Factors Action Implementation

(220) Detailed HF analysis to help to define and refine the statement of the system requirements or design. This will include studies such as (1) analysis and evaluation of Single 'Operational Improvement cluster' (2) analysis and evaluation of Integrated 'Validation Areas' and (3) Evaluation of the roles of actors (i.e. their new jobs). The analysis and evaluation will be undertaken HF Analysis Studies, Real Time Simulations and Focussed HF studies:

- **HF Analysis Studies**. Detailed HF analysis will help to define and refine the statement of the system requirements or design. This will include studies such as:
  - Allocation of function between human and machine - HF Allocation of Function + Application of Automation Principles,
  - Situation Awareness; workload; teamwork; roles - Task Analysis +Timeline Analysis,
  - Procedures - Task Analysis +TRACEr-lite,
  - HMI - Echoes and HF Design Standards,
  - Trust - Application of Automation Principles,
  - Skill set - Cognitive Task Analysis.

Inputs required	*HF Plan, initial HF requirements; HF objectives*
Outputs	detailed HF requirements for RTS

- **Simulations**. HF Evaluations will be undertaken to validate and provide evidence for the adequacy of HF issues using the following sets of tools during Real-Time Simulations and focussed human factors studies:
  - Situation Awareness – SASHA, SHAPE; SAGAT (RTS),
  - Workload – AIM, SHAPE; NASA-TLX; ISA; Psycho-physiological (RTS),
  - Procedures & Skills - Task Analysis + RTS ,
  - HMI - Usability tests; prototyping + eye-tracking,
  - Recoverability from human error and system failure - RTS (+CARA),
  - Teamwork – SKATE, SHAPE (RTS),
  - Trust – SATI, SHAPE (RTS),
  - Roles – RTS.

Inputs required	Results from HF Analysis; HF Methods for simulations
Outputs	qualitative and quantitative measures

Stage 5. HF Case Consolidation

(221) Does the analysis show that the operators can meet the specified system performance (in a real environment, with proposed training).

(222) Based on initial objectives, the task analysis, human factors objectives, the HF issues identified, results from the simulations, human factors information from the HIFA website, and HF principles, a set of requirements will be identified to inform the design.

- human performance constraints and requirements to be placed into the system specifications,
- identify human factors issues that must be resolved,
- identify tasks and analyses to be undertaken to ensure human performance goals are met,
- ensure fulfilment of the applicable human performance and safety requirements.

Inputs required	project technical specifications; simulation results
Outputs	HF requirements and specifications

Human Factors Areas	**HF Tools to support the development of the concept**	**HF Methods to measure and test the design during real time simulations**	
		Relative Approach (compare OI to a baseline)	**Absolute Approach (example 'red line' classification)**
Automation	HF AOF + Automation Principles	Qualitative Questionnaire Debriefing	x
Procedures (incl communications)	Task Analysis + TRACEr-lite	Task Analysis during RTS Qualitative Questionnaire Debriefing	x
HMI	Echoes + Standards	Usability tests Eye-tracking	Usability tests (cut-off 80%)
Team work	Task Analysis + Timeline Analysis	SHAPE tool – SKATE Qualitative Questionnaire Debriefing	x
Roles & responsibilities	Task Analysis	Qualitative Questionnaire Debriefing	x
Skill set	SHAPE Skills Change Tool + Cognitive Task Analysis	Qualitative Questionnaire Debriefing Task Analysis during RTS	x
Situation awareness	Task Analysis + Timeline Analysis	SHAPE tool – SASHA SAGAT	SASHA (cut-off 70%)
Mental workload	Task Analysis + Timeline Analysis	SHAPE tool – AIM NASA-TLX ISA Psycho-physiological # of RT communications + see Manning, 2001 table	Combination of AIM, NASA-TLX & ISA (cut-off 70%)
Human error & recovery	Task Analysis + TRACEr-lite	Observation of errors Error Scenarios Interviews Debriefing	Loss of separation data Risk classification scheme (severity x frequency)
Trust	HF Automation Principles	SHAPE tool - SATI	SATI (cut-off 80%)

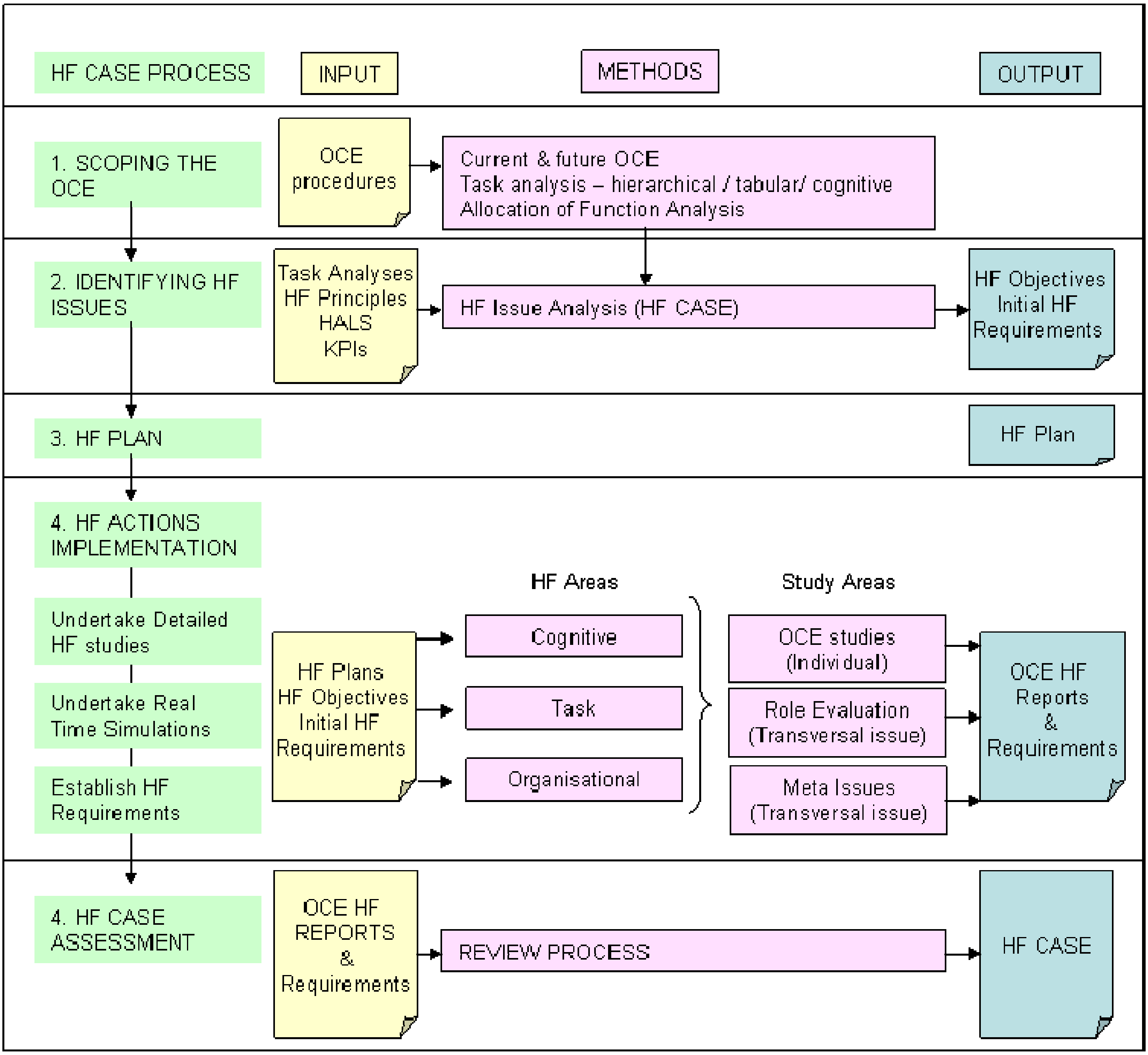

Figure 2. Human Factors Approach

ANNEX B - 2. Human Factors Methods and Analysis

(223) This section of the document defines the human factors tools and methods required for the development and assessment of the CONOPS, as well as the criteria which can be used to assess whether or not the human factors principles have been met.

Human Factors Tools and Measures

(224) In order to ensure that the SESAR CONOPS are acceptable with regard to the ten human factors principles, it is important that human factors methods are used in the development of the concept as well as to assess whether or not the concepts are valid with regard to the 10 human factors principles.

(225) Table C1 illustrates the types of tools that can be used to support the development of the concept (column 2), and measures that can be used to test if the concept allows the actors to work at an adequate level with regard to the 10 human factors principles, such as situation awareness, workload, etc (column 3).

HF Principles *~ what is important*	**HF Tools** *~ to help develop the design*	**Measures** *~ to test the design is right*
1. Right allocation of function	HF AOF + Automation Principles	HITL Experiments
2. Adequate situation awareness	Task Analysis + Timeline Analysis	SASHA, SAGAT (RTS)
3. Adequate mental workload	Task Analysis + Timeline Analysis	AIM, NASA-TLX, ISA, Psycho-physiological (RTS)
4. Adequate procedures (including communications)	Task Analysis + TRACEr-lite	Task Analysis + HITL
5. Adequate HMI	Echoes + Standards	Usability tests + prototyping + eye-tracking
6. Recoverability from human error and system failure	Task Analysis + TRACEr-lite	RTS (+CARA)
7. Adequate team work	Task Analysis + Timeline Analysis	SKATE (RTS)
8. Adequate trust	HF Automation Principles	SATI (RTS)
9. Adequate skill set	Cognitive Task Analysis	Task Analysis + RTS
10. Adequate roles	Task Analysis	Real-Time Simulations

Table C1. Human Factors Methods to support concept development and human factors assessment

(226) For more information regarding each of these tools and measures, please refer to the EP3 / MTV Human Factors Guidance document.

ANNEX B - 3. Analysis of Human Factors Data

(227) The human factors assessment of the SESAR CONOPS will need to identify whether or not the SESAR CONOPS 'passes' the 10 human factors criteria. These criteria are yet to be developed on the basis of x, y, z(see Table x). TBD in August.

(228) Figure 2 represents the overall results from the human factors assessment of a particular concept (e.g. ERASMUS) in a graphical format. Each of the human factors principles that have been assessed during the ERASMUS project will have their own scale. For example, mental workload may have a 5-point scale of the adequate level of workload (not over- or under-loaded), whereas situation awareness *has* a 7-point scale to illustrate the adequate level. The green line indicates the level at which ERASMUS needs to reach to be acceptable in terms of the human factors principles. Beyond the green line indicates where ERASMUS exceeds the "acceptable levels" on the human factors principles. This graph gives the reader an overall picture of how well ERASMUS is performing with regard to human factors, at an individual Operational Improvement level.

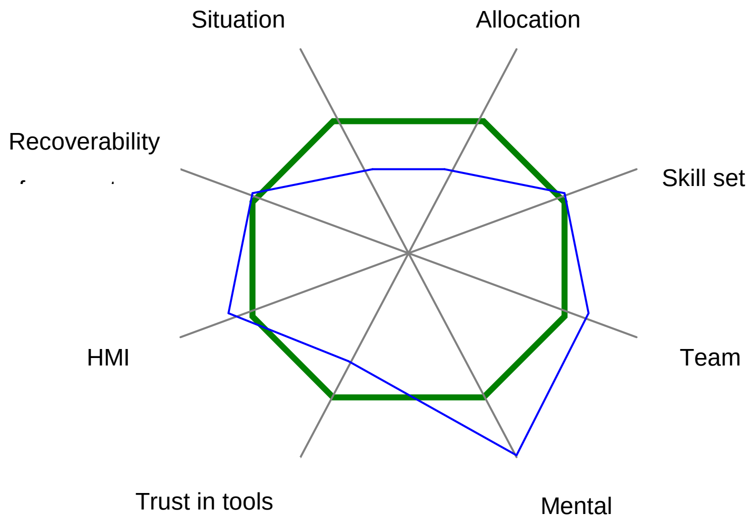

Figure 2. Graphical representation of the results of the human factors assessment of a particular *Operational Improvement* (e.g. ERASMUS)

(229) At the system level, a similar representation will be undertaken to show how the interaction of the various Operational Improvements (OIs) – such as ERASMUS - impacts controller and pilot performance with regard to the human factors principles, where a number of the OIs will be represented on the same spider-diagram (see Figure 2).

End of annexes