Long-Term and Innovative Research

WP-E Thematic Programme

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1 INTRODUCTION

1.1 Purpose

This is the Thematic Programme for SESAR Work Package E (WP-E), Long-Term and Innovative Research. Its purpose is to set out a framework for the research to be undertaken within the work package, describing how the work is to be structured and detailing a number of research themes to be addressed. This second version provides an update to the version published in 2010 and now acknowledges the work that is already launched, showing where additional complementary research has a high priority for SESAR.

1.2 Who should read this document

This document is for the benefit of researchers that might wish to participate in SESAR long-term and innovative research activities. Participation means involvement in one or several of the main programme elements, networks, PhDs and projects, which are described in Chapter 3.

The air traffic management (ATM) domain, including communication, navigation and surveillance (CNS) provide many research challenges that could be addressed by a wide range of academic disciplines. Interest and participation is thus encouraged not just from researchers currently involved in these domains, but also from those who have expertise not previously applied to the challenges. The transition from exploratory research, primarily for knowledge, and the research and innovation necessary to apply this knowledge into future developments in ATM is a key focus for this version of the Thematic Programme, consequently researchers in fields of applied researcher and SME participants are also the target audience.

This is a public document and its wide distribution is encouraged.

1.3 Background

In recent years the European air traffic management community has been calling for the creation of a single structure to coordinate all ATM research. The SESAR Joint Undertaking ("SJU"), was established under council regulation (EC) 219/2007, as last modified by Council Regulation (EC) 1361/2008, on 27 February 2007 (SJU Regulation) and is henceforth responsible for *"… carrying out specific activities aimed at modernising the European air traffic management system by coordinating and concentrating all relevant research and development efforts in the Community"*. This includes long-term and innovative research.

Arguments for a positive approach to long-term research and innovation in all branches of industry are well understood. In particular, the need to build the European economy on strong foundations of knowledge, research and innovation is reiterated in many EU declarations and treaties, and is seen as the key to growth, jobs and prosperity.

This is just as true for CNS/ATM as it is for any other industry. It is vital that research competence is built and maintained so that Europe can play a significant and lasting role in the global arena. A framework is needed that will coordinate research and maximise potential returns.

The SESAR Programme includes a work package specifically devoted to long-term and innovative research in ATM: Work Package E (WP-E). This work package has been active since 2010 having launched a number of dedicated activities coordinated as an integral part of the SESAR Programme as well as building appropriate interfaces and/or consultation with other research and development efforts.

1.4 The Long Term & Innovative Research vision

The key contribution from WP-E will be twofold:

Firstly, it will be a catalyst to create a healthy European research capability for ATM and related CNS that will persist beyond the lifetime of the current SESAR development programme.

Secondly, it will make provision and provide funding for research activities that are not currently planned within the 'mainstream' SESAR development work packages. This will include exploratory/fundamental research, applied research and addressing known ATM problems with new methods and approaches.

1.5 Document layout

Chapter 2 of this document gives further background, with an explanation of the three phases of SESAR, and how Work Package E fits in. Chapter 3 outlines the two key structural elements of Work Package E: Research Networks and Research Projects.

Chapter 4 describes the five research themes of WP-E. They provide subject matter guidance for the preparation of Research Project proposals as well as research challenges. General background and reference material is listed in Chapter 5. Reference material specific to each of the Research Themes is given in the relevant section.

1.6 Glossary of terms used

Term	Definition
ANSP	Air Navigation Service Provider
ATFCM	Air Traffic Flow & Capacity Management
ATM	Air Traffic Management
CDM	Collaborative Decision Making
Joint Undertaking	A public private partnership established under European law.
LoA	Levels of Automation
NM	Network Manager
NOP	Network Operations Plan
Research Theme	A specific subject or area that will form the basis of WP-E research work for both Research Networks and Research Projects.
SES	Single European Sky. European air traffic management legislative framework comprising both technical and regulatory parts required to build a seamless European air transportation system. Current status is SES-II.
SESAR	Single European Sky ATM Research. The European air traffic control infrastructure modernisation programme - the technical part of the Single European Sky initiative.
SESAR Scientific Committee	A high level committee of academics and researchers that supports the SESAR Joint Undertaking to help develop, review and validate the scientific aspects of the work.
SJU	SESAR Joint Undertaking; the responsible body created to co-ordinate and concentrate all ATM R&D in Europe.
WP-E Research Network	A grouping of researchers with common expertise and interest that exists for the purpose of knowledge generation, sharing and dissemination. Research Networks include PhD's studies.
WP-E Project	A specific piece of research with defined budget, timescales and deliverables.

Term	Definition
Research Challenge	This is a particular type of applied research that addresses a known yet unsolved problem in ATM research. This could be approached with traditional or new techniques or a combination of both; a challenge will usually consist in transferring the results of past research and applying it to new applications and/or novel technologies in search of innovative and ground-breaking results.

2 SESAR AND THE CNS / ATM CONTEXT

2.1 SESAR Joint Undertaking & the Master Plan

The SESAR Master Plan sets out and maintains the relevance and viability of a complex programme whose implementation requires the involvement of a large number of stakeholders, each with their own business objectives. To manage the programme and achieve the goals the SESAR Joint Undertaking (SJU) was formally established in 2007 by the European Council. This is a public-private partnership comprising two founding members, the European Commission and EUROCONTROL, together with a number of industrial and operational entities who will work together to maintain and execute the plan.

The SESAR Joint Undertaking (SJU) manages the programme of work which includes maintenance of the SESAR Master Plan in response to the need for operational and technological modernisation of the European air traffic management system. It coordinates and concentrates all relevant ATM research and development efforts in the European Union engaging a broad range of public agencies, industries, research centres and universities in a public-private partnership involving around 3000 experts across more than 70 organisations.

The SESAR programme realises airborne and ground system developments, including aircraft and airport systems integration as well as 4-D trajectories, information management, automation and network management in order to meet challenging capacity, safety, cost and environmental goals. It delivers validated pre-industrialised results on an annual basis from research already performed as well as initiating exploratory research to generate relevant knowledge and applied research leading to the prospect of new development and innovations. See www.sesarju.eu for more information.

The SESAR Master Plan was formally endorsed by the Council in March 2009. Known henceforth as the European Air Traffic Management Master Plan, it "constitutes the basis for establishing the SESAR Joint Undertaking's work programme and the development phase of the SESAR project". The Master Plan is regularly reviewed and an updated version will be published in July 2012.

2.2 The operational concept

The SESAR concept of operations is based on the ICAO Global ATM Operational Concept and has been further detailed during the SESAR Development Phase, detailing the following priority strategic business needs:

- Airport Integration and Throughput aims at achieving a full integration of airports into the ATM network as nodes in the system, ensuring a seamless process through Collaborative Decision Making (CDM). Airports will contribute to achieve SESAR performance goals through the Increase of runway throughput and improved surface movement management in combination with trajectory management, airborne spacing tools and precision navigation techniques e.g. reducing air and ground holding leading to reduced noise and environmental emissions per flight.

- Conflict Management and Automation aims at substantially reducing controller task load per flight, while meeting safety and environmental SESAR goals and without incurring in a significant increase in Air Navigation Service Provider (ANSP) costs, through an intense enhancement of integrated automation support. However, human operators will remain at the core of the system (overall system managers) using automated systems with the required degree of integrity and redundancy.

- Moving from Airspace to 4D Trajectory Management entails the systematic sharing of aircraft trajectories between various participants in the ATM process to ensure that all air and ground partners have a common view of a flight and have access to the most up to date data available to perform their tasks. It enables the dynamic adjustment of airspace characteristics to meet predicted demand with distortions to the business/mission trajectories kept to a minimum. Whenever possible, the necessary tactical interventions are considered at the gate to gate trajectory level and not only at sector level, taking into consideration the wider impact on the trajectories concerned as well as on the Network. This is based on the operational and technology scope definition of the trajectory management framework, its content, performance and access across all flight phases and associated concept and technology developments. The SESAR Trajectory Management Framework (TMF) specifies the structure needed to achieve the safe and efficient creation, amendment and distribution of the Reference Business/Mission Trajectory (RBT/MT) including the RBT/MT information content & quality, the Actors involved, and the Services associated with trajectory information (e.g. creation, proposed revision and update processes).

- Network Collaborative Management and Dynamic/Capacity Balancing includes enhanced Network Management through a dynamic, on-line, collaborative Network Operations Plan (NOP) fully integrated with Airport Operations Plan (AOP) considering all relevant actors' planning aspects including airports, airspace users, decision makers, etc. The Network Manager (NM) assesses the evolution of traffic and airspace demand, identifies capacity/traffic imbalances, develops Air Traffic Flow & Capacity Management (ATFCM) scenarios for capacity shortfalls through a CDM process involving all concerned actors and records the agreed scenarios in the NOP. When necessary the NM proposes modified routes to the Aircraft Operators based on the published alternative routes. The Aircraft Operators submit the revised user preferred trajectories integrating the ATM constraints. The NM monitors the demand capacity imbalances, identifies and coordinates with relevant stakeholders to take appropriate actions for demand capacity balancing. NOP and AOP are then updated accordingly. This linking of AOP/NOP parameters (ABT and User Preferred Trajectory) optimise the network and airport management by timely and simultaneously updating AOP and NOP via SWIM, providing Network and Airport Managers with a commonly updated, consistent and accurate Plan. The NOP becomes the Information Delivery Service Unit for all planning units in the Network: Airport Operators, ANSP, Airspace Users and Network Manager. Throughout the lifecycle of a flight, a layered and collaborative planning consists of successive planning phases from long term to medium and short term, involving all ATM stakeholders in Collaborative Decision Making processes to progressively build the Network Operation Plan (NOP) through the sharing of more and more up to date and precise data once the day of operations approaches. As the day of operation approaches, the Aircraft Operator's plans and the details regarding airspace management become richer in detail and less subject to variation. For military flights, if a specific airspace structure is needed, it is fully integrated into the trajectory description. A collaborative planning process is applied to the trajectory in a number of iterations, refining it with constraints arising from new and more accurate information. If ATM constraints have to be applied, the preferred way to integrate them is achieved through a collaborative process with the Airspace Users in order to achieve the best business or mission outcome.

- Traffic Synchronisation covers all aspects related to improving arrival/departure management and sequence building in en-route and TMA environments in order to achieve an optimum traffic sequence resulting in significantly less need for ATC tactical intervention, and the optimisation of climbing and descending traffic profiles. As a consequence flights are able to fly closer to their optimum trajectories bringing benefits across predictability, efficiency, safety, capacity, and environment.

In support of the priorities above, new technologies providing more accurate airborne navigation and optimised spacing between aircraft to maximise airspace and airport capacity will be embedded into a harmonised and interoperable air and ground operational and technical architecture supporting the needs of all European regions.

2.3 The need for long-term and innovative research

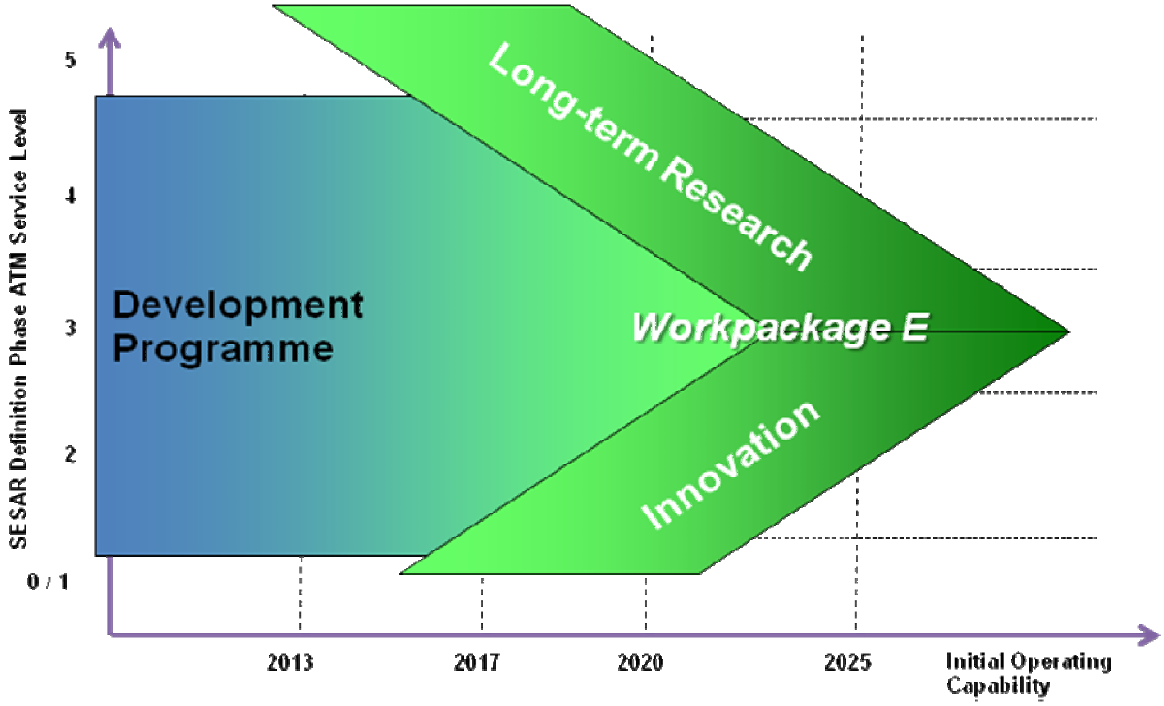
Innovation and knowledge development are cornerstones of the European Union's strategy for prosperity and growth as set out, for example, in the Lisbon Agenda. The SESAR Definition Phase acknowledged that this innovation is required in the ATM sector as much as anywhere. Deliverable D4 states that *"…it is very important that creativity and innovation are stimulated today in preparation for the future improvements and that appropriate levels of investment funds and resources are put in place to address these planning horizons, i.e. beyond the 2020 target … As with other industrial sectors, ATM research should be promoted within academia, serving the dual purpose of stimulating creativity whilst preparing staff for tomorrow's applications."*

In order to address this, SESAR Work Package E (WP-E), was launched. It includes not just research into concepts for implementation beyond the nominal SESAR timeframe of 2020, but also encourages innovation that could be beneficial at any time.

2.4 Work Package E scope and its construction

The scope of Work Package E may broadly be stated as covering ATM, CNS and related research activities not currently addressed by the other work packages of the SESAR work programme. More specifically this means two things for the scope of WP-E:

- Research is needed for timescales beyond the nominal SESAR time horizon of 2020, beyond the limits of the current concept. In this respect work may build on the existing Master Plan or it may be more detached and futuristic.
- Innovative research is needed to identify and investigate topics that might bring new approaches and solutions for benefit in both the short and longer term.



Scope of Work Package E

More generally, research within WP-E will explore novel, unconventional areas, involving new technologies, concepts or ideas. It may seek to apply existing methodologies and techniques in new ways, potentially applying scientific disciplines that have not previously been brought to bear on air traffic domains.

WP-E efforts are organised through the construction of two functional instruments:

1. Research Networks which provide a structured way to build research knowledge, competence and capability that should serve the industry in the long term. Each Research Network comprises members and participants from academia, research centres, industry/SME etc. that share a common expertise and interest in a relevant air traffic management or transportation domain. Research Networks are organised in accordance with at least one of the Research Themes. Management of a portfolio of PhD research projects is an essential part of a Research Network.
2. Research Projects explore new ideas focussed on the long term but may also result in innovative solutions applicable in short- and mid-terms. Interdisciplinary approaches are explicitly encouraged as they have demonstrated potential to develop innovative solutions.

Contracts for each instrument are let following open calls. WP-E today consists of two research networks including a total of 20 PhD studies and a portfolio of 18 projects. Summary information on the functioning of projects and networks as well an overview of present activities is given in subsequent sections.

For all questions concerning Work Package E the SESAR web site is the definitive source for current information (http://www.sesarju.eu/programme/workpackages/wpe) – it is updated on a regular basis.

Finally, the SJU has established a Scientific Committee to provide advice, to the SJU Executive Director, on the overall SESAR work programme from a scientific perspective. The Committee takes a particular interest in Work Package E, for example to advise on thematic content and strategic direction. Refer to the SJU website (http://www.sesarju.eu/players/committee) for more information on the Scientific Committee.

3 WP-E NETWORKS, PHD'S AND PROJECTS

3.1 Introduction

WP-E is built around two main instruments, Research Networks and Research Projects as described in section 2.4. Important considerations for networks, PhDs and projects are:

- The ability of networks to attract high-quality research partners and contributions from both within and outside of the ATM domain;
- The degree of innovation in the projects;
- The demonstration of the application of existing research knowledge to tackle new and interesting problems with the potential for results that bring significant benefit to ATM.
- The potential for fruitful exchange between WP-E research and mainstream SESAR work programme activities;
- The desire for 'quick wins': opportunities for results to be applied for short-term benefit;
- Opening ATM research to domains not traditionally represented in ATM research.

All activities are expected to demonstrate both progress and tangible results, and these objectives will be verified by regular review.

Only participants from within ECAC are eligible for WP-E funding.

3.2 Networks and PhDs

3.2.1 Networks and PhDs vision

Networks are central to WP-E research coordination. A network is a grouping of researchers from academia, SMEs, industry and/or research establishments that share common interests and expertise in a particular field of research aligned to a research theme.

Each network is expected to be a key driver in its field of interest to exchange and develop knowledge and expertise relevant to ATM. Co-operation within networks is expected to lead to outcomes that have a lasting and widespread impact on ATM research across Europe.

Specific eligible activities include:

- Research coordination, including organisation of and engagement in events for the discussion and dissemination of research results to both scientific and non-scientific communities. Organised events will include scientific conferences and workshops. WPE Research Projects will be expected to participate in relevant coordination activities and participation from other related EC and SESAR projects will be encouraged;

- Knowledge development, including initiatives in post-graduate training (e.g. doctoral symposium, tutorials or summer school) and mobility of researchers with a view to developing a lasting research capacity for CNS/ATM in Europe; knowledge management, including maintenance of a public repository of relevant research results from within and beyond the Network; the Research Network should also consider providing information to European wide research databases.

- Research Network development: any activity required to ensure the Research Network develops and retains the role of key driver in their field, including managing the ascension of new network members;

- Management of PhD portfolios: each network is expected to manage a portfolio of PhDs sponsored by WP-E including the selection of theses and candidates and ensuring progress and communication of research results.

Research Networks are expected to forge strong relationships with industry to build and develop their reputation and influence, and potentially attract additional external investment. They will have a particular role to identify and promote successful or promising research, accompanying it into the applied domain with industrial partners.

A specific role of the networks is to ensure coordination with relevant WP-E projects with a view to encouraging communication between the network and the projects, between the projects themselves and with other relevant SESAR work packages and projects outside WP-E. Networks have a role in providing feedback to relevant projects on a regular basis. To that end, WP-E projects are assigned to one of the existing networks.

In the future WP-E is looking to develop additional research coordination in new subject areas through the use of 'mini-networks' as described in section 3.3.1.

3.2.2 Networks and PhDs today

Following WP-E's first call two research networks have been established:

- HALA! – Towards Higher Levels of Automation in ATM is coordinated by Universidad Politécnica de Madrid (Spain) and comprises 13 other members from European academia, research centres and industry. HALA! has published a Position Paper on Automation in ATM, is organiser of the International Conference on Application and Theory of Automation in Command and Control Systems (www.ataccs.org/) and a dedicated summer university course on automation in ATM and oversees a portfolio of 13 PhDs. For more info about HALA! please consult www.hala-sesar.net/
- ComplexWorld – Mastering Complex Systems Safely is coordinated by the Innaxis Research Institute (Spain) with five additional members from European academia and research centres. ComplexWorld has published Position Paper, will be running parallel sessions at ATOS (lr.tudelft.nl/atos) and ECCS (www.eccs2012.eu/). ComplexWorld oversees a portfolio of 7 PhDs. For more info about ComplexWorld please consult www.complexworld.eu

A third small network has been launched as part of WP-E project ALIAS to bring together legal experts and others to address liability issues related to increased levels of automation and changes in the role of human operators in the ATM system. This network is by nature different from HALA! and ComplexWorld in that it forms an integral part of project activities. This approach is appropriate considering the specialist subject matter. For more info about ALIAS please consult www.aliasnetwork.eu.

3.3 Projects

3.3.1 Projects vision

WP-E projects are specific co-financed research activities outside the scope of other SESAR work packages that fall into one or more of the Research Themes described in Section 4 and could address a specific Challenge. These will mainly be oriented for the long-term but will potentially have application in the shorter term.

Projects are expected to generate scientific knowledge that increases understanding of the future CNS/ATM system and demonstrate the potential of novel technologies, methods or concepts. They will be required to disseminate their results via appropriate channels, e.g. regularly publish in appropriate peer-reviewed conferences and/or journals.

Projects are contractually independent from the Networks but are expected to actively connect with the appropriate network where the subject matter aligns with the network's theme. Collaboration will be ensured by assigning each project to the network most relevant for the research it addresses.

Like networks, project proposals are solicited through calls managed by EUROCONTROL on behalf of the SJU. Project proposals are evaluated, according to published criteria, by a panel of independent experts. Projects have a maximum duration of 30 months.

Depending on the portfolio of projects finally selected there may be synergies between projects that would justify network-like activities, e.g. organising workshops or joint publications such as position papers. When and if such synergies become apparent EUROCONTROL on behalf of the SJU may call upon projects to make provision for such activities and form a mini-network. Funding in such cases will be provided through an ad-hoc work order.

3.3.2 Project Challenges

Project proposals that address a specific challenge are encouraged. A challenge is a particular type of applied research that addresses a known yet unsolved problem in ATM. A challenge can be approached either with traditional or new techniques or a combination of both; a challenge will usually consist in transferring the results of past research to new applications and/or technologies in search of innovative and ground-breaking results. Example challenges are presented in the sections that describe the research themes; the list provided under each theme is by no means exhaustive or complete and proposals that address a challenge not presently described are invited to describe this new challenge.

Interdisciplinary approaches are encouraged.

3.3.3 WP-E Projects today

WP-E currently includes a portfolio of projects distributed across the automation, complexity and legal research themes. This updated Thematic Programme has been updated to reflect the coverage already achieved and to encourage participation into areas of research thought to bring greatest value to SESAR.

A description of the existing projects can be found at www.sesarju.eu/programme/workpackages/wp-e-sesar-long-term-and-innovative-research-335/research-projects--500 and the main thematic coverage is shown in Section 4 where the individual research themes are described together with currently existing WP-E Research Projects in these areas.

3.3.4 New WP-E Research Project proposals

When submitting project proposals potential bidders will be encouraged to familiarise themselves with the portfolio of existing WP-E projects. Bidders will also be expected to familiarise themselves with the mainstream SESAR work programme, i.e. the SESAR work packages and projects that are not part of WP-E. Excessive duplication with existing projects must be avoided, although a clear definition of an interface and/or consultation mechanism describing a relationship with either WP-E or other SESAR projects, if relevant, must be provided.

Proposals that repeat existing research will be deemed out of scope. It may be that new project bids propose research that follows on from existing projects. In this case bidders must carefully explain their assumptions, how they will access and make use of previous results etc.

Innovative proposals are encouraged and the degree of innovation and relevance to ATM of a proposal is an evaluation criterion.

The selection process is described in the supporting call documentation.

4 WP-E RESEARCH THEMES

4.1 Overview

The research themes presented in this release of the Thematic Programme were defined following broad consultation with experts from academia, industries, research organisations, the SESAR Scientific Committee and the European Commission. Sources consulted during the preparation of this document include:

- a participant questionnaire distributed during the SESAR Innovation Days 2011 soliciting research ideas, problems and challenges;
- a paper produced by the SESAR Scientific Committee entitled 'Future Directions for Research in Air Traffic Management from 2020 to 2050';
- consultation with military, ANSP, operational and industry experts in the SJU;
- consultation within EUROCONTROL;
- ACARE document: 'Report on Long-Term and Innovative Air Traffic Research';
- ACARE document 'Flightpath 2050 – Europe's Vision for Aviation';
- the ComplexWorld Research Network Position Paper;
- the HALA! Research Network Position Paper;

- plus a number of other relevant publications. These documents and surveys generated several hundred ideas, many of them having at least some aspect of duplication giving rise to groupings. The groups of ideas thus generated were classified into approximately ten major themes which were then reduced to the five presented below. Principal considerations when finalising the research themes included:

- the potential for added value to the existing SESAR work programme;
- the need to think beyond the current SESAR timeframes;
- the potential for making a tangible difference in support of a 'paradigm shift' in ATM;
- the potential for engaging new academic disciplines in ATM research;
- the need to avoid overlap with other European activities (e.g. FP7 projects, CleanSky);
- the potential to exploit interfaces with other European activities by exchanging information and in some cases sharing the scope of a larger research subject/challenge;
- the need to concentrate and communicate relevant research in CNS/ATM from many sources into a relevant network.

The number of themes is limited in order to provide focus to WP-E given its limited resources. The themes described in this release are an evolution of an initial set of four themes that formed the basis of two earlier WP-E calls.

The research themes described further in the following sections of this document are:

1. Toward Higher Levels of Automation in ATM (updated)
2. Mastering Complex Systems Safely (updated)
3. System Architecture and System Design (new)
4. Information Management and Optimization (new)
5. Enabling Change in ATM (new, including earlier themes 'Economics and Performance' and 'Legal Aspects of Paradigm Shift')

These themes serve as guidelines for those wishing to submit proposal in response to the WP-E call. The descriptions given here are brief, and it is anticipated that bidders will interpret and enrich them according to their own expertise, keeping in mind the vision and objectives for WP-E, described earlier.

In some cases the research themes described below have deliberate scope overlap as the grouping is intended to provide a workable classification rather than discrete topic separation with no interaction. Consequently it is also the role of projects to look beyond the primary theme (when appropriate) and with the support of the Research Networks to build bridges both across the themes as well as across the content of the theme (see reference to mini-network formation in section 3.3.1).

Bidders will have to propose activity within one of the themes described below, although it is expected that interfaces to either existing activities in other themes, aspects of other themes or with other non WP-E research may exist; when this is the case the interfaces and means of exploiting them should be described in the proposal.

WP-E research is expected to be undertaken in a multi-disciplinary manner. In particular ATM expertise should be available to ensure that the assumptions underlying the work are plausible and appropriately detailed.

4.2 Theme 1: Toward Higher Levels of Automation in ATM

4.2.1 Synopsis

This research theme is concerned with research into higher degrees of automation of ATM systems, up to and including full automation. An important element will be the integration of airborne and ground-based systems, technology solutions for General Aviation in new ATM operating concepts and infrastructure, heterogeneous traffic and new traffic participants, the evolution of the human role thus managing the transition to higher degrees of automation.

4.2.2 Background and motivation

The ATM system has evolved at a remarkably slow pace and today is still largely based on paradigms and technology that have not fundamentally changed for decades. There are undoubtedly a number of valid reasons for this, but significant progress in ATM will not be possible without a much bolder vision that, in particular, allows significantly increased levels of automation.

The current SESAR Concept of Operations was developed with the understanding that “humans will constitute the core of the future ATM System’s operations” [D3]. The underlying human-centred philosophy may be adequate for the SESAR timeframe but places significant constraints on the design of ATM systems for the more distant future. This theme seeks to relax this constraint and open up new conceptual possibilities while still bearing in mind the need to manage transition from today's system to one that involves higher degrees of automation. This transition includes aspects of evolution of skills as well as training and recruitment.

Various schemes of Levels of Automation (LoA) have been proposed; e.g. [Parasuraman et al.] distinguish between ten levels of automation for the functions information acquisition, information analysis, decision selection and action implementation. In this classification complete departure from all human intervention occurs at automation Level 10. ATM systems today probably do not exceed level 3 or 4 for either function, the human remaining fully in control. Allocating an appropriate degree of automation requires understanding the capabilities both of human operators and automation. Whilst human performance characteristics have not changed over several millennia, the performance of computers and automated systems is continuously evolving, rapidly increasing the potential for automation as demonstrated by fast-increasing degrees of automation in safety-critical domains such as automotive and aircraft systems. It seems inevitable that in time substantial parts of the air traffic management system may also be subject to higher degrees of automation, possibly up to full automation in certain areas or for certain types of operation/service.

The introduction of higher degrees of automation is a complex undertaking since it must include careful consideration of all benefits, risks and costs. Whilst a key driver for automating is often cost-efficiency, this must be balanced against aspects such as increased system complexity, evolution in human roles and capabilities, the relationship between automation and aviation safety and the need to ensure safe recovery from system degradation. The transition to a future ATM system involving higher degrees of automation will need to be carefully managed from both technological and human perspectives, and this requires detailed attention to ensure viable and effective transformation steps exist, covering the technological, operational and human perspectives. It may also be necessary to consider the legal implications of new developments (see Theme 5). The introduction of new technologies probably implies coexistence of varying levels of automation in different tightly-coupled subsystems. Ensuring that human skills and capacities evolve to cope with this is a complex challenge.

Experience from application areas with higher degrees of automation, especially from the perspective of guidance and control theories, may inspire progress in the area of ATM.

4.2.3 Outline of research

This research area will study the application of high degrees of automation to one or several components of the air traffic management system (with or without the involvement of human operators) taking into account transition issues. Specific research topics may include:

- Introduction of <u>technology supporting higher degrees of automation</u> including integration and transition issues such as technological change management, the coexistence of subsystems with different levels of automation and geographical transition from autonomous to ATC-based operations;

- New paradigms, concepts and technology for the human- machine interaction, including new methods of processing and displaying information, new display and input technology, advances in decision support tools and human-machine interfaces supporting changes in roles and automation levels supported by the full range of human factors considerations;
- Designing resilient highly automated systems and defining recovery paths in degraded modes of operation; monitoring for system degradation; assessing the ability and prerequisites for human role in recovery from system degradation;
- Integration and management of various constraints on trajectories originating from different Decision Support Tools and/or meteo-related constraints;
- Understanding the predictability-flexibility trade-off and guidance for choosing the appropriate level of determinism for different components, situations and timelines in the ATM system;
- Integrating state-of-the-art communication technologies into the ATM automated system, in particular in the pre-tactical and tactical phases of Air Traffic Flow Management in order to increase the predictability of the whole ATM system;
- Conducting applied research into use of technologies and infrastructure supporting General Aviation integration into concepts of operation including SESAR and beyond.

4.2.4 Challenges

Specific research challenges may include:

- Demonstration/proof of the feasibility of fully automating parts of the ATM system and understanding the trade-offs between all costs, risks, uncertainty and benefits when introducing higher degrees of automation, including the repercussions on overall system complexity as a cost. Examples from other application areas (e.g. energy) where increasingly complex tasks have been automated have shown that barriers to automation are often non-technical and that automation has in many cases significantly increased safety and efficiency. It seems a question of when rather than whether automation will have advanced to the point where a fully automated ATM system is feasible.
- Proof of concept of innovative Air Traffic Control paradigms that exploit modern communication, navigation and surveillance technologies to achieve better performances in terms of cost, flexibility, punctuality and environmental performance. One-Controller-One-Flight Seamless Air Traffic Control is an example of human-centred automation that could be further investigated taking into account the achievements by SESAR as the starting point. Other examples can be the paradigm dealing with fully automated air cargo transportation system with a focus on modern information and communication technologies and human roles on the management and use of those technologies.
- Integration of heterogeneous traffic and new traffic participants, managing the increasing complexity of a traffic system with a wider spread of performance characteristics and integration of unmanned aerial systems. New traffic participants, such as unmanned aerial vehicles and personal air transport vehicles will emerge and need to be integrated into the air traffic management system. In addition, traditional aircraft with different operating characteristics may play a stronger role in the future leading to a less uniform traffic mix than today.
- Full integration of General Aviation in the SESAR Concept: to date scheduled, business and military aviation are well represented in the SESAR Concept and the deployment of SESAR technology will focus on these. The characteristics and interests of General Aviation (GA) are solicited and integrated to a lesser extent. The challenge is to research, develop and/or apply cost-effective technology to support the GA community in the SESAR concept as well as the evolution towards increasing automation levels by linking the cockpit technologies with the automation and support in the evolving ATM and supporting CNS infrastructure.

4.2.5 Applicable disciplines

The types of expertise that might be brought to bear to address these issues include but are not limited to:

- Automation
- Communications
- Computing
- Guidance and control engineering and theory
- Distributed algorithms
- Optimization
- ATM/CNS ground, satellite and airborne technologies
- Human reliability assessment
- Human factors engineering
- Mathematics and modelling
- System safety assessment
- System Engineering
- Resilience engineering
- Engineering history
- Change Management
- Avionics
- Aeronautics

4.2.6 Related ongoing WP-E projects

Relevant ongoing WP-E projects in the area of Automation include:

- SUPEROPT: The goal of this project is to make numerical trajectory optimizers more suitable for human supervision for selected application areas and look-ahead times of human operators. For more details see http://www.hala-sesar.net/superopt

- STREAM (Strategic Trajectory de-confliction to Enable seamless Aircraft conflict Management): The STREAM project aims to investigate innovative strategic trajectory-de-confliction algorithms that can reduce the conflict management automation gap between the pre-departure and flight execution phases. See http://www.hala-sesar.net/stream

- TESA (Trajectory prediction and conflict resolution for Enroute-to-enroute Seamless Air Traffic management): TESA will extent the current en-route model to the remaining phases of operation and develop real-time uncertainty models; it will also use an advanced trajectory prediction model developed in the first part of the project together with aircraft intent, to develop a model for optimal and strategic resolution of conflicts. See http://www.hala-sesar.net/tesa

- MUFASA (Multidimensional Framework for Advanced SESAR Automation): The MUFASA project aims to develop a framework for designing future levels of ATM automation, based primarily on human-in-the-loop simulation, including “heuristic conformity” or the fit between human and automation solutions to medium term planning and separation conflicts. See http://www.chpr.nl/mufasa.htm

- ADAHR (Assessment of Degree of Automation on Human Roles): This project assess the human factors aspects in the future operational environment (timeline 2020 – 2050) in selected operational ATM environments using Gaming techniques. See http://www.adahr.eu/

- C-SHARE: aims to provide a framework for a complete functional airspace representation (that is, model of the work domain) that underlies both the design of human-machine interfaces as well as ground and air-automation tools to address problems associated with a rigid allocation of tasks between automation and human by design and a cognitive mismatch between human and automation. See http://c-share.d-cis.nl/

- UTOPIA (Universal Trajectory Synchronization for Highly Predictable Arrivals Enabled by Full Automation) addresses advanced trajectory management models, sources of uncertainty and advanced arrival management and communication. See http://www.hala-sesar.net/utopia

- ZeFMaP (Zero Failure Management at Maximum Productivity in Safety Critical Control Rooms): The project aims to improve productivity and safety of the highly automated ATM control room by implementing a four-step productivity driven Human Factors (HF) method incorporating permanent improvement cycles. See http://www.hala-sesar.net/zefmap
- SPAD (System Performances under Automation Degradation) aims at: (a) understanding, modelling and estimating the propagation of automation degradation in ATM; (b) estimating the consequences of automation degradation on ATM performance; (c) supporting an effective intervention for the containment of automation degradation. See http://www.hala-sesar.net/spad

4.3 Theme 2: Mastering Complex Systems Safely

4.3.1 Synopsis

This research theme focuses on air traffic management as a system of systems, with the objective of characterising the sources and consequences of its complexity and emergent properties, especially those related to safety and system performance. This will provide valuable insight into the system-wide impacts of change that are today not well mastered. 'System' in this context is understood to refer not only to technical aspects but rather to the full range of socio-technical considerations.

Since this theme concentrates on the application of complexity theory to the ATM domain some overlap with other themes, in particular Theme 3 (System Architecture and System Design) and Theme 4 (Information Management, Uncertainty and Optimization) is anticipated. This is to be expected and allows for a scientific approach to specific areas from different perspectives.

4.3.2 Background and motivation

"It is clear that widely different systems, composed of many interacting units, generate under certain conditions a characteristic common phenomenology, the most prominent signature of which is the emergence of new patterns transcending the characteristics of the individual units. The promise of the science of complexity is to provide […] common tools to tackling complex problems arising in a wide range of scientific domains." [GIACS]

Using this new 'science', complex phenomena in the fields of economics, social sciences, and biology and communication technologies have been tackled successfully over the last decade or so. The complexity of the air traffic management system, and of the interactions of its subsystems, is undeniable, so the ambition of this theme is to explore the potential of applying these rapidly maturing mathematical analyses and modelling tools to bring immediate and tangible benefits for the ATM domain.

A research interest of this theme is to understand the behaviour of the overall system when changes are introduced in one or more subsystems. Several changes have been applied to ATM in recent years without a full understanding of the potential system-wide consequences (emergent behaviour). SESAR plans to make a large number of performance 'improvements', and their combined influence needs to be well understood and controlled, especially considering the impact on safety. Could these 'improvements' have consequences that are hidden from traditional validation approaches? How and in what sequence should they be introduced? The science of complexity could help answer some of these questions.

Design characteristics of complex systems and their impact in safety critical domains have been studied [Perrow]. This research theme has the potential for suggesting resilient and agile designs which are more conducive to the safe and expeditious introduction of new technologies or operational procedures.

4.3.3 Outline of research

Concretely, this research theme may address the following:

- Multi-scale modelling, both in time and space: these models should identify and capture the different temporal and spatial scales of the ATM system of system required for understanding the issue at hand. The models should be exploited to bring out new insights, dependencies or governing laws.
- Emergent behaviour: Use complex systems theory and models to better understand emergent properties such as delay, predictability and safety. Exploit the models for forecasting or evaluation of evolutionary growth scenarios.
- Non-determinism: Investigate the impact of uncertainty on overall system behaviour. Study how sensitive the system is to measurement errors or lack of precise data. Evaluate non-deterministic models for both the technical and human components of the system.
- Disturbances and graceful degradation: Study the reaction of the ATM system to disturbances (including sudden convective weather), resilience, disturbance propagation, graceful/ intelligent degradation and recovery and intelligent healing of the ATM system of systems.

Consider the added complexity of systems that span organisational boundaries and the relationship with safety and business performance.

- Assessing the true costs of system complexity for all system stakeholders, including design, certification, industrialization, maintenance, use and performance-related costs.
- Learning: demonstrate the benefits of specific learning algorithms to better understand properties of complex systems, e.g. mastering uncertainty, coping with evolution, identifying emergence etc.

4.3.4 Challenges

Specific research challenges may include:

- Demonstrating the feasibility of complex systems methods and approaches to ATM: the discipline of complex systems theory and its related modelling techniques are relatively new and have been applied, with some success in other domains, such as social sciences, biology and traffic modelling.
- Defining suitable performance metrics of Air Traffic Management from a complex system theory point of view: Because of the complexity of the ATM system, of which human actors are still the main components, and the performance ceiling of the systems is dependent on human performances that vary from one individual to others, several ATM system metrics such as capacity and workload are not easily measured, locally and globally. As an example, capacity of sectors in a FAB cannot be summed up to establish the indicator of capacity of the FAB, and "airspace capacity' is a fundamental metrics in ATFM that needs to be well defined, or replaced by a more scientific or theoretic metric that can capture the local and global behaviour of the ATM system. Complex system theory could be one approach to this critical element of ATM system. Solid understanding of these metrics would help developing a solid model-based system for ATM that would be closer to reality, and that may lead to realistic model-based simulations of ATM complex systems.

4.3.5 Applicable disciplines

The types of expertise that might be brought to bear to address these issues include but are not limited to:

- System dynamics and other approaches to non-linear systems
- Complex systems theory
- System Engineering (Architectural pattern theory, service orientation & orchestration)
- Control theory
- Graph theory and topology
- Safety methodologies
- Probabilistic modelling
- Natural computing [Kari], including self-organising systems
- Artificial Intelligence, in particular learning
- Robotics (motion planning, swarm modelling)
- Statistical Physics
- Ergonomics

4.3.6 Related ongoing WP-E projects

Relevant ongoing WP-E projects in the area of Complex Systems include:

- ONBOARD (Probabilistic Network Based Operations ATM R&D) aims at improving the performances of the ATM system (e.g. predictability) in the short term planning phase by developing new models and algorithms to enable the Network Manager to better manage the two factors that account for two thirds of the ATFM delay in Europe (weather and knock-on effects), in particular by addressing the key sources of uncertainty (weather forecast, unscheduled demand, air users response to disruptions). For more information see http://complexworld.innaxis.org/projects.html
- ASHiCS (Automating the search for hazards in complex systems): investigates how meta-heuristic search can be used to manipulate and configure ATM simulation models, so that a

huge number of pathways and subsystem combinations can be explored without the need for manual intervention.

- POEM (Passenger-oriented enhanced metrics): aims at developing novel metrics to quantifying delay propagation and delay from a passenger-centric point of view considering that the average delay of a flight and the average delay of a passenger on that flight may be very different indeed.
- MAREA (Mathematical approach towards resilience engineering in ATM) aims at developing a mathematical modelling and analysis approach towards the application of resilience engineering in ATM, and to demonstrate its usability through application to SESAR 2020 scenarios.
- COMPASS (Safety Management in Complex ATM System of Systems using ICT approaches) addresses the challenge of how to identify combinations system-level events (such as the health status of individual devices) as they are happening and issue warnings to operators early enough to take action and prevent catastrophic failures. For more information see http://complexworld.innaxis.org/projects.html
- CASSIOPEIA (Complex Adaptative Systems for Optimisation of Performance in ATM): attempts the application of complex systems modelling technique on three scenarios selected during the project, including agent-based modelling. See http://complexworld.innaxis.org/projects.html
- ELSA (Empirically grounded agent based models for the future ATM scenario): The ELSA project will (a) perform an extensive statistical analysis of data of the ATM system with Complex Systems theory techniques in order to characterize statistical regularities; (b) develop a hierarchy of an Agent Based Model of increasing complexity and degree of realism, to simulate the emergent properties of the trajectory-based SESAR scenario; and (c) design and implement a prototype decision support tool, to monitor, predict (based on the Agent Based Model) and intervene on the airspace. See http://complexworld.innaxis.org/projects.html
- NEWO (Emerging Network-Wide effects of inventive Operational approaches in ATM): explores the potential of innovative modelling techniques applied to the study of the Air Transport network interactions, specifically the effect that new approaches to demand-capacity balancing (such as UDPP) has on emergent properties in the ATM system. See http://www.newo-sju.eu/

4.4 Theme 3: System Architecture and System Design

4.4.1 Synopsis

This research theme addresses the architecture of the ATM system[1] and proposes informed decisions about design choices that, in the past have often been constrained by considerations of expediency or legacy. It also addresses the process of designing the ATM system, including allocation of tasks between air and ground, the impact on technologies and certification, equipment supply and operator responsibility as well as the need to simplify and accelerate innovation in ATM. Finally the practical realisation of system level resilience of the ATM system, i.e. its capacity to react gracefully to system disturbances, is also addressed in this theme.

Some overlap with other themes is anticipated, in particular Theme 2 (Mastering Complex Systems Safely). This is to be expected and allows for a scientific approach to specific areas from different perspectives.

4.4.2 Background and motivation

The advantages of standards in system development are widely recognised and some attempts have been made to harmonize the development of ATM tools and concepts. Yet the ATM system – or rather ATM systems today – have largely developed in an evolutionary fashion and the rationales for design choices are often historic rather than based on an overall system performance evaluation. SESAR has developed a Concept of Operations and a Master Plan that to a certain degree constitutes a departure from the past and aims at a top-down approach to designing and developing a new ATM system. However a purely top-down functional design of a system as complex as ATM may rapidly become unmanageable, consisting of many multiply-interconnected and tightly coupled subsystems. New system-wide information management (SWIM) philosophies should allow much looser 'data' coupling ideally leading to greater flexibility and resilience.

There are many design choices in constructing the overall ATM system architecture and the implications of many of these are at present not well understood. New approaches to system design have developed in other industries and may inspire ATM. Research can help understanding the benefits and disadvantages of different system architectures and this, indeed, is what this research theme addresses.

Related to the system architecture, the process of designing – and innovating – in ATM can at present best be described as a difficult and slow process. Using the safety or liability argument alone does not explain why the innovation cycle in ATM is twice that on the flight deck: has the ATM system become too complex, and too tightly coupled? Have we sufficient control of the interdependencies and feedback loops between its subsystems? Will increased interdependency lead to increased risk and potential for large-scale failures or, on the contrary, can the complexity be exploited to help cope during degraded modes of operation? Furthermore, one could ask whether problems of complexity are purely technical or whether they are at least partly institutional. Can the ATM innovation process, including certification, be simplified and accelerated? Can a more agile ATM system be developed?

The resilience of the ATM system, i.e. its ability to recover from or at least react gracefully to system disturbances, is a consequence of its architecture and interactions. A better understanding of the mechanics of resilience and how they depend on system properties is required to build safer and more efficient ATM systems.

4.4.3 Outline of research

- New approaches to designing the ATM system and its components inspired by other industries, including participatory design;
- Understanding the system innovation lifecycle and making ATM innovation faster and more cost-efficient while maintaining demonstrable control and determinism of the outcome in support of safety, security and other pre-operational arguments;

[1] ATM system in this context refers to the technical system, including its physical components and information flows and the consequences design choices have on system performance, such as capacity, safety, cost-efficiency.

- Describing the characteristics of loosely vs. tightly coupled systems and concepts of operations in ATM and their implications on overall system performance, complexity and resilience;
- Service orientation: introduction of new players or new service offerings in the air transport system with an impact on the roles and functioning of traditional players, including the unbundling of services traditionally provided by one player.
- Studying the applicability and advantages of multiple service levels and tailored service provision, including its system-wide (emergent) effects.
- Assessing the role of standardisation in ATM system development as well as how open-source, off-the-shelf technology and mobile computing could be more widely used considering, for example, issues of safety and security.
- Designing agile systems, i.e. scalable, configurable systems that allow adaptation to different traffic/ATM system characteristics: develop design principles that facilitate the introduction of changes in one or more subsystems, or the adaptation to external changes. Develop methodologies that determine which local or subsystem changes will most effectively generate required overall performance improvements. Study the interaction and potential trade-offs between agility and resilience.
- Quantifying the resilience of the ATM system, present and future, both with respect to small perturbations and catastrophic perturbations (as described by different magnitudes and time-scale) as well as early warning signs indicating likely system degradation.
- Building resilient systems: quantifying the impact of architectural and system design choices, including higher degrees of automation, on the resilience of the ATM system and proposing an engineering/system design process that builds resilience into the ATM system. new design paradigm for resilient system and services, e.g. delay-free travel

4.4.4 Challenges

Specific research challenges may include:

- Design an open source ATM: The increasing availability of open source software and recognised benefits of open-source software inspire the question whether such an approach would be feasible in a high safety-high security environment such as ATM. Can approaches from the open-source community be applied to ATM? How can safety, security, legal, regulatory or other concerns be dispelled?
- Reduce the innovation life cycle by 50 %: With an average of almost 20 years from concept development to operational use the ATM innovation life cycle is twice that of avionics systems with certification accounting for a significant part of the duration. A faster and more efficient innovation cycle is needed but at the same time safety and security requirements must not be sacrificed. Does the ATM system need de-complexifying? Would an open or distributed design process accelerate innovation? Can certification be streamlined?
- Conduct a high-level design exercise and determine the transition steps to a fully service oriented and scalable architecture for ATM in Europe, while taking into account how safety, security and liability concerns will be addressed.

4.4.5 Applicable disciplines

The types of expertise that might be brought to bear to address these issues include but are not limited to:

- Industrial design
- Software development and architecture
- Formal methods for system specification and verification
- Mathematics and operations research
- Consumer electronics and gaming
- System dynamics and other approaches to non-linear systems
- Complex systems theory
- System Engineering (Architectural pattern theory, service orientation & orchestration)

- Automation
- Communications
- Guidance and control engineering and theory
- Distributed algorithms
- Mathematics and modelling
- Resilience engineering
- Engineering history
- System Architecture
- Enterprise Architecture

4.5 Theme 4: Information Management, Uncertainty and Optimization

4.5.1 Synopsis

This theme addresses the management of data and information, both online and historical. It also includes aspects such as system wide information sharing, application of optimization techniques and the study of uncertainty related to trajectory-based operations beyond the scope of SWIM in SESAR today.

This is a broad theme so overlap with other themes is anticipated, in particular Theme 2 (Mastering Complex Systems Safely). This is to be expected and allows for a scientific approach to specific areas from different perspectives.

4.5.2 Background and motivation

The advent of concepts such as collaborative decision making and system wide information management are accompanied by needs for increased information sharing between various actors, beyond the traditional information sharing in ATM that is often based on a peer-to-peer architecture. New approaches to information sharing may evolve (such as the 'Cloud') in which application and information are not necessary stored together and in which both are accessible to a wider range of actors. The advantages of advanced information management are undeniable but many challenges remain to be addressed: An increased number of stakeholders will require access to and feed information into data sets; whilst traditionally a range of different interfaces and technologies are used for information sharing leading to known interface problems. How can information best be stored and accessed and how to ensure it is up-to-date? Stakeholders may need to provide commercially sensitive data which must be protected from competitors. New service providers may enter ATM and need to qualify for access to sensitive data. Do new concepts of information management lead to unexpected, potentially network-wide effects? How do errors propagate through the information management system? Which implications would moving from information stored centrally to distributed information stored at source have in terms of responsibility and potentially liability? What are the true costs and benefits of information and what is the optimum amount and quality of information?

Related to the management of information is its use for purposes of optimization. A wider range of data and information will be available, both online data and historic data, that will allow more focus and powerful optimization techniques. Aircraft track and performance data and digital meteo data will be available with greater resolution and quality. Planning and scheduling information from airports, airlines and service providers could be used for optimization purposes, e.g. in the context of system wide information management. On the other hand, the availability of high-fidelity track and performance data will permit data mining and statistical analysis on historical data sets. These may permit studying reliability and uncertainty which will inform the management of online data, e.g. for scheduling and trajectory management.

Finally, uncertainty related to external influences such as weather but also to the precision with which an aircraft will execute its business trajectory will remain and this leads to two challenges: on the one hand optimization techniques must be robust to uncertainty, e.g. the solution found must still satisfy the constraints if the aircraft deviates from the planned trajectory within the agreed margins. This may significantly increase the complexity of the optimization, potentially leading to unpractical computation times. On the other hand understanding the levels of uncertainty in various stages of the flight and under various environmental conditions may inform the required precision in trajectory management and conflict resolution.

4.5.3 Outline of research

- New approaches to data and information management in ATM, including new paradigms for system wide information management including the flight deck such as advanced, safety critical, cloud technology (including non-technical issues such as responsibility, confidentiality, liability, reliability); this includes designing resilient data networks (note link to Theme 'System Design and System Architecture').

- Advanced optimization techniques for trajectory-based operations, including heuristic optimization, control techniques and numerical optimization, data mining and statistical tools; optimization techniques must consider uncertainty in trajectory and environment;
- Assessing cost and benefit of information and information sharing and providing guidance as to the difference between information and knowledge as well as how much information is enough;
- Understanding and modelling resolvable and inherent uncertainty in trajectory-based operations for various levels of navigation performance, including the uncertainty caused by atmospheric effects and addressing the precision-flexibility trade-off;
- Overall ATM process optimization through analysis of the stability/uncertainty of its information sub-processes;

4.5.4 Challenges

Specific research challenges may include:

- The SWIM-Cloud: Cloud-computing seems to hold great potential for greater efficiency in computing and data storage. At the same time data integrity and security are issues that need addressing. Whether or not the concept of cloud computing has potential for system wide information management has yet to be demonstrated.
- System-Wide Resource Planning: Data integration and updates in real-time as well as results of optimised procedures, actions, schedules and plans shall be made available to all other users of the ATM system, consistently and under high security from external threads. Similar to Enterprise Resource Planning using in business organization, ATM System-Wide Resource Planning can make use of data on SWIM, extended for specific operational purposes and for different actors of the systems such as AOC, Airports, ATC, Airlines, etc.

4.5.5 Applicable disciplines

The types of expertise that might be brought to bear to address these issues include but are not limited to:

- Data mining, probabilistic modelling and statistics
- Constraint programming
- Numerical optimization (e.g. MILP, heuristic,)
- Nature-inspired optimization techniques (simulated annealing, genetic algorithms)
- Complex systems theory, system dynamics and other approaches to non-linear systems
- Social sciences
- Human-machine interface design
- System engineering
- Control theory
- Information technology
- Communication technology

4.6 Theme 5: Enabling Change in ATM

4.6.1 Synopsis

This research theme covers economic and performance as well as legal issues associated with the introduction of the future ATM system, both SESAR and beyond. It will examine how these factors and their related requirements drive new developments in the ATM system. It also includes aspects such as certification, liability, competition and intellectual property rights, at levels ranging from institutional down to detailed operations. Specific aspects not mentioned here, for example regulatory aspects, are explicitly excluded from this theme.

4.6.2 Background and motivation

The evolution of the ATM system as foreseen in SESAR will lead to significant changes both technical and non-technical. Studies by the PRU [PRU] and others have produced detailed work that provides significant insights into the costs and performance of the current system. Yet, understanding and quantifying the true costs as well as the performance benefits of the future ATM concept of operations for all stakeholders of the ATM system remains a significant challenge. At the same time studies are required to assess how economic mechanisms could be applied to accompany and incentivise the introduction of new tools and ATM concepts of operation.

The future ATM system will lead to significant changes in roles and responsibilities, e.g. where the responsibility for maintaining safe separation between aircraft may be delegated, temporarily or permanently from the air traffic controller to the flight crew; where data management becomes decentralised; and where higher levels of automation are introduced to support the air traffic control task. Anticipating these changes requires an understanding of their legal implications (liability of the controller, pilot, information and technology aspects etc.).

Shortcomings of the present ATM system are manifold and well documented; yet at the same time the ATM industry suffers long lead times for the introduction of improvements and new technologies. Indeed, development and especially certification processes in ATM are lengthy and complex even for relatively small and decoupled improvements, so applying existing approaches to an ‘overall’ SESAR system, or at least to big chunks of it, would be of another order of magnitude. Research is needed to show how the innovation can be encouraged and certification of new tools and concepts can be accelerated without detrimental effects on safety and performance.

4.6.3 Outline of research

In keeping with the objectives of WP-E the research should be innovative, and in particular should not reproduce the extensive analyses already done during the SESAR Definition Phase or other initiatives. The issues outlined above, together with others that will emerge during the lifetime of SESAR, may be addressed from a broad perspective but may also be based on an analysis of the specific consequences of introducing new SESAR technologies.

Specific research topics may include:

- <u>Overall assessment of the true cost and performance benefits</u> of the new ATM concept of operations for all ATM stakeholders, including modelling trade-offs and multi-objective / multi-stakeholder optimization in air transport;
- <u>Applying economic incentives</u> for demand-capacity balancing such as demand-oriented pricing, performance-based costing of service provision including different service levels, and trading and auctioning of access to ATM resources;
- Analysis of benefits and disadvantages of <u>different ATM financial models</u> such as cost recovery vs. performance-based costing and financing through user-charges as opposed to collective financing (public service) and development of new financing paradigms for financing ATM service provision including the appearance of new service providers;
- Benefits and disadvantages of the use of <u>regulatory tools vs. incentives schemes</u> in managing innovation and change, both technical and non-technical;

- Incentives for cooperation between ATM stakeholders (e.g. in the context of introducing collaborative elements such as SWIM or CDM) and balancing cooperation with competition;
- Analysis of models for technology diffusion and adoption based on an understanding of SESAR proposals taking into account of, inter alia, economic incentives, competition and the impact of institutional and regulatory frameworks. Examples from other industries may provide useful indicators;
- Management of innovation and change at European level, including IPR, innovation management, incentives schemes for innovation addressing all stakeholders of the ATM system and the liabilities and risks associated with innovation in ATM;
- New air transport systems and their operations, such as UAV, Personal Air Transport Vehicle, etc.
- Legal implications, especially regarding regulation and liability of new operating paradigms including increasing levels of automation; changes in roles of the human operator(s); system-wide elements which imply new modes of sharing critical and/or commercially sensitive information; and delegation of separation responsibilities e.g. to the cockpit.
- Approaches to security management applied across ATM system development and its evolutions.

4.6.4 Challenges

Specific research challenges may include:

- Conformance to SES II cost performance targets and beyond: Indirect costs of operations in Europe are thought to be too high, comparing with those in the USA. Economic incentives and well as social incentives from different perspectives shall be clarified in order to confirm the areas of possible optimization. In particular, what SESAR could bring to current ATM system in terms of performance improvement (in particular unit cost of operations), and beyond the time scale defined for SES II.
- Conformance to SES II environmental targets, especially on the European performance targets dealing with CO_2 emissions. With tightening environmental constraints, airlines shall be taking strategic decisions (in terms of number of flights versus frequency of flights) in order to cope with these constraints while still trying to improve business competitiveness. New operating paradigms will certainly have impacts to airlines operations and vice-versa

4.6.5 Applicable disciplines

The types of expertise that might be brought to bear to address these issues include but are not limited to:

- Legal
- Philosophy (ethics, responsibility)
- Safety
- Security
- Complex systems
- Automation
- Agent-based modelling, gaming
- Marketing and business administration
- Economics
- Environmental sciences
- Behavioural sciences
- Human Factors engineering
- Finance
- Innovation & change management
- Mathematics
- Operations research, optimization
- System and control engineering

4.6.6 Related ongoing WP-E projects

Relevant ongoing WP-E projects in the area of Complex Systems include:

- POEM (Passenger-oriented enhanced metrics) aims at developing novel metrics to quantifying delay propagation and delay from a passenger-centric point of view considering that the average delay of a flight and the average delay of a passenger on that flight may be very different indeed.
- ALIAS: addresses analyses present and future technological developments in ATM and their impacts on ATM liability, assesses current responsibility regimes and proposes future developments. The expected outputs include a methodological tool, "The Legal case" that will support the introduction of automation in ATM, ensuring that relevant legal aspects are taken into consideration at the right stage of the design, development and deployment process. For more information see www.aliasnetwork.eu/

5 APPLICABLE DOCUMENTS

SESAR Definition Phase deliverable D3: The ATM Target Concept, 2007.

SESAR Definition Phase deliverable D4: The ATM Deployment Sequence, 2008.

SESAR Definition Phase deliverable D5: The SESAR Master Plan, 2008.

SESAR Joint Undertaking Description of Work,

(The above documents are available at http://www.sesarju.eu/)

ACARE: Report on Long-Term and Innovative Air Traffic Research (2010)

Call for Tenders No 10-220719-A Long-term and Innovative Research: Second call for WP-E Research Projects Technical Specifications

EU Lisbon strategy: http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/00100-r1.en0.htm

EUROCNTROL SENSE project, http://www.eurocontrol.int/humanfactors/public/standard_page/SENSE.html

European Performance Review Report (PRR), available at http://www.eurocontrol.int/articles/european-ans-performance-review

Flightpath 2050 – Europe's Vision for Aviation. Accessible via http://www.acare4europe.com

Hollnagel, Erik; Woods, David D. and Leveson, Nancy: Resilience engineering: concepts and precepts. Ashgate, 2011.

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Parasuraman, R., Sheridan, T.B. and Wickens, C.D: A model for types and levels of human interaction with automation. IEEE Transactions on Systems, Man and Cybernetics, Volume 30, Issue 3, page 286-297, 2000.

Perrow, C. Normal Accidents: Living with High-Risk Technologies. Princeton University Press, 1999.

Tackling Complexity in Science. A NEST Pathfinder initiative of the European Commission, DG Research, (EU 22423) 2007.

Websites:

European ATM Masterplan portal https://www.atmmasterplan.eu

SESAR Joint Undertaking: http://www.sesarju.eu/

HALA!: http://www.hala-sesar.net/

ComplexWorld: http://www.complexworld.eu/

ALIAS: http://www.aliasnetwork.eu/

ACARE: http://www.acare4europe.com