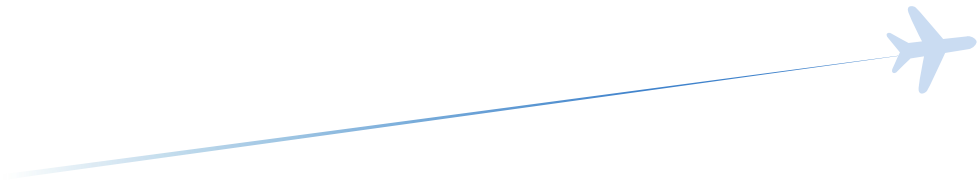

Final Project Results Report

Deliverable ID:	**D1.6**
Dissemination Level:	**PU**
Project Acronym:	**PACAS**
Grant:	**699306**
Call:	**[H2020-SESAR-2015-1]**
Topic:	**Sesar-11-2015 ATM Performance**
Consortium Coordinator:	**UNITN**
Edition date:	**21 February 2018**
Edition:	**00.01.00**
Template Edition:	**02.00.01**

Founding Members

EUROPEAN UNION EUROCONTROL

SESAR JOINT UNDERTAKING

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Document History

Edition	Date	Status	Author	Justification
00.00.01	05/02/2018	Draft	Elda Paja	Table of contents and assignment of

				responsibilities
00.00.02	05/02/2018	Draft	Fatma Basak Aydemir	Insert content on WP4
00.00.03	07/02/2018	Draft	Fabiano Dalpiaz	Lessons learned on WP4
00.00.04	12/02/2018	Draft	Elda Paja	Technical deliverables
00.00.05	13/02/2018	Draft	Per Hakon Meland	Content on WP3
00.00.06	13/02/2018	Draft	Martina Ragosta	Content on WP 5 and 6, link to SESAR
00.00.07	14/02/2018	Draft	Elda Paja	Operational context
00.00.08	19/02/2018	Draft	Martina Ragosta	Next steps
00.00.09	20/02/2018	Draft	Elda Paja	Synergies with other projects, complete revision
00.00.10	21/02/2018	Draft	Martina Ragosta	Complete revision
00.01.00	21/02/2018	Document for submission	Elda Paja, Paolo Giorgini	Prepare document for submission

Copyright Statement

PACAS

PARTICIPATORY ARCHITECTURAL CHANGE MANAGEMENT IN ATM SYSTEMS

This deliverable has received funding from the SESAR Joint Undertaking under grant agreement No 699306 under European Union's Horizon 2020 research and innovation Programme.

Abstract

PACAS is about supporting *change management* in Air Traffic Management (ATM) systems, relying on the *end-to-end inclusion* of ATM domain stakeholders through *gamification*. The project constructs a platform that facilitates understanding, modelling and analysing changes in the ATM system at different layers of abstraction with the help of a gamified change management process.

To accommodate the expertise of the various domain stakeholders PACAS relies on the provision of *multiple views* at the strategic layer, in order to represent and analyse different objectives (i.e., Key Performance Areas – KPAs), namely those related to economical, organizational, security, and safety concerns. The PACAS process intends to keep the views aligned, understand the impact of change and finding an optimal solution (trade-off) among the various objectives through a *novel participatory design process*.

In this document, we provide a summary of PACAS accomplishments and contributions, along the feedback obtained and lessons learned, to then conclude with further developments of PACAS in the ATM Community and in the integration of Exploratory Research projects into the SESAR mainstream and future SESAR 2020 program.

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Note to Authors (please reveal formatting ¶ to see instructions)

Please explain in sufficient detail the scientific work performed so that the reader can identify which deliverables might be of interest in case he wants to read more detail. **It is expected that most of its content can be reused for the H2020 Publishable Summary.**

1 Executive Summary

Air Traffic Management (ATM) systems are complex systems of systems. Understanding all possible consequences of a design decision in an ATM system is a challenge due to the complexity of ATM systems and the existence of tight interdependencies within the ATM architecture. Knowing the implications of change(s) over the whole system is crucial to support decision-making, while making sure that the ATM system does not suffer from any issues with respect to functionality, safety, security, performance, cost efficiency, or other desired characteristics of a well-functioning ATM system.

Given that decision-making involves the consideration of more high-level objectives, the change management process should involve multiple ATM domain stakeholders, one for each given objective, in order to explore a vast space of alternatives and agreeing on optimal solutions. It becomes, thus, crucial the active ***participation*** of stakeholders. However, given the variety of experts, their different areas of expertise, as well as their geographical distribution, *participatory change management* requires (i) *user engagement* and (ii) *tools* to *support* and *facilitate* the work of experts along their interaction.

To address the first concern, in recent years, ***gamification*** has been used as a tool to engage participation with the help of elements, such as leader-boards or challenges between users. As for the second concern, a ***multi-perspective***, ***model-based approach*** provides important benefits in that: (i) it allows analyzing individual perspectives without the need of a holistic representation; (ii) it handles complexity through ***automated reasoning techniques*** in a transparent way to find optimal solutions as a trade-off among different objectives.

In its two years, PACAS has made the following technical contributions to tackle the aforementioned problems:

1- A novel gamified change management process that relies on the end-to-end inclusion of ATM domain experts, ranging from decision-makers (managers and team leaders) to analysts (experts)

2- Refined modelling notations for each KPA (security, safety, economic and organizational), which are at the basis of the multi-view modelling approach, and a shared model that apart from providing an overview of the status of the change under analysis, provides great benefits to an informed decision-making process

3- A range of automated reasoning techniques spanning from local reasoning performed within a single modelling environment, to those across views that are crucial for facilitating the work of modelers (intelligent cross-view alignment – ICVA and change impact propagation – CIP) and for supporting multi-criteria decision making (three different techniques for MCDA)

Through the end-to-end inclusion of ATM domain stakeholders, PACAS has not only validated the PACAS concept, but it has defined and refined the requirements for PACAS process and platform in an iterative fashion until their final release.

The participation to various events has helped disseminate the PACAS concept not only within the ATM community but also in other contexts, such as the academic and industrial practice.

In this document, we provide an overview of the PACAS project context and objectives, along a summary of the work accomplished and the results achieved in these two years. Finally, we propose a roadmap for the exploitation of the PACAS concept as part of the next steps.

2 Project Overview

2.1 Operational/Technical Context

ATM systems are complex systems-of-systems that are managed via a layered architectural model, which includes operational, organisational, and technical layers to ease handling complexity. Due to strong interdependencies in an ATM system, any change introduced in any of these layers might trigger changes both within the same layer and in the other layers. Understanding all possible consequences of a design decision in ATM systems is a challenge due to the complexity of these systems and the existence of tight interdependencies within the ATM architecture. A careful consideration of possible changes together with their implications on the entire ATM system is crucial to support decision-making, while making sure that the ATM system does not suffer from any issues with respect to functionality, safety, security, performance, cost efficiency, or other desired characteristics of a well-functioning ATM system.

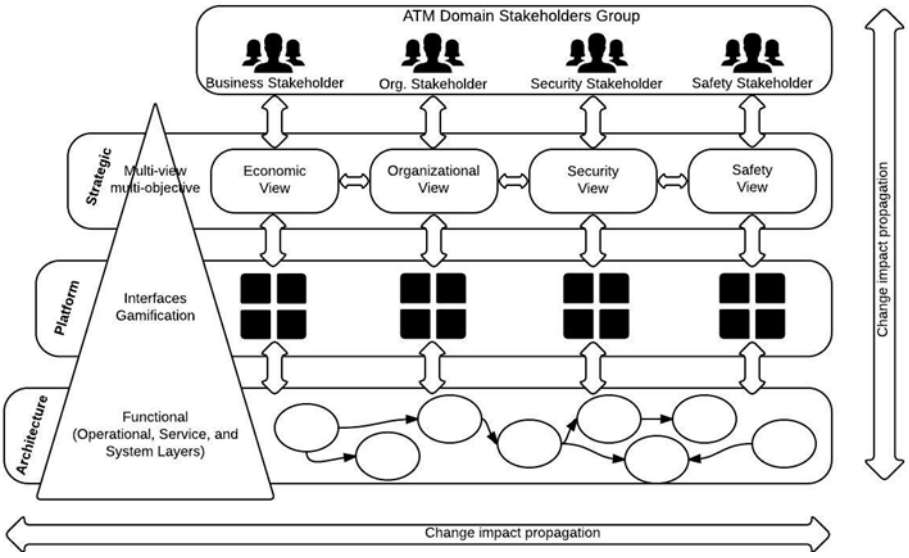

Figure 1: Multi-view multi-objective gamified participatory design process for ATM architectural change management

PACAS is about supporting change management in ATM systems from an architectural point of view, relying on the end-to-end inclusion of ATM domain stakeholders through gamification. The project constructs a platform that facilitates understanding, modelling and analysis of changes in the ATM system at different layers of abstraction. The approach to finding optimal solutions is based on a novel participatory design process to handle change management. The process relies on the provision of multiple views (to accommodate the expertise of the various domain stakeholders), as well as the representation and analysis of multiple objectives, namely those related to economical, organizational, security, and safety concerns (Figure 1).

2.2 Project Scope and Objectives

The very tight network of interdependencies that arose and evolved over decades without any

central design authority makes change management in ATM a very difficult problem. Impacts of design choices are very difficult to be evaluated and ATM domain stakeholders may have specific and conflicting strategic objectives to maximize. The main objective of PACAS project is to deliver a Change Management Platform, which will facilitate understanding, modelling and analyzing changes in the ATM System at different layers of abstraction.

To achieve this aim, PACAS has relied on the end-to-end inclusion of ATM domain stakeholders in the whole design process starting from requirements definition until the final release of the platform. The PACAS platform is complemented with a participatory change management process, which defines the roles and how they are to be engaged in collaborating in the decision-making process in the analysis of a given change.

The PACAS project will reach its aim through the achievement of the following objectives:

1. *Develop a multi-view participatory design process to support change management* for the (re)design of European ATM Systems. The process will provide participants a semi-structured way of modelling, and a set of guidelines for open decision-making to include all participants in the modelling process. The process will be *gamified* to increase engagement of the participants. A proof-of-concept platform will be developed to assist the developed design process and include gamification elements.
2. *Develop essential concepts for modelling ATM systems, to capture strategic objectives* of the involved ATM domain stakeholders (*safety, security, economic and organizational concerns*) in *separate views*, emphasizing the sociotechnical (involving social, organizational, and technical systems) nature of ATM systems.
3. *Develop automated reasoning techniques that support the analysis and the decision-making activities*. The first type of techniques focuses on preserving alignment between multiple perspectives/views and the impacts of changes made in one view on the other views. The second type of algorithms aims to identify a trade-off among stakeholders' different preferences and ranking the various options that are being compared.
4. *Demonstrate and evaluate the practical use of the participatory design process and of the modelling and reasoning techniques*. Reference scenarios will be created to validate the modelling languages developed, as well as qualitative and quantitative analysis techniques. The usability and the effectiveness of the modeling language will be validated by the ATM domain stakeholders. Reasoning techniques, multi-objective optimization functions and automatically found optimal solutions are validated by expert opinion.

2.3 Work Performed

The work performed during the project lifecycle is elaborated through seven Work Packages (WP). Each WP describes the main content developed by the Project Team.

2.3.1 Work Package 1

This WP is a transversal activity addressing the entire duration of the project. This work package deals with general administrative responsibilities and tasks for coordinating the financial, legal and technical aspects of the project, in order to ensure the successful completion of the objectives in line with guidelines from the SJU, the Contract and the Consortium Agreement.

WP1 has been active during the whole project lifetime. The objective is to ensure an efficient and active coordination of the project through administrative and organizational tasks, and monitoring of the financial project components. Performed activities have included:

- General project administration;
- Preparing and post-processing of European commission reviews from the consortium-side including support in the implementation of recommendations from SJU;
- Preparing, executing, and post-processing of scheduled project meetings;
- Preparation and submission of the management related parts of the reports to SJU.
- Management of financial management platform;
- Preparation of the financial reports to the SJU;
- Controlling of the overall budget;

Maintenance of the project intranet and data repository for the consortium (Sharepoint platform), which has been continuously updated, containing all important documents.

2.3.2 Work Package 2

PACAS WP2 is about developing the participatory design process for change management in the ATM architecture, the overarching outcome of the project. This process is meant to support ATM domain stakeholders in dealing with change management at the strategic layer focusing on four key performance areas (economic, organizational, security, and safety), in order to understand the impacts and repercussion of change before it is adopted.

Our approach supports the ATM domain stakeholders by means of an online collaborative portal where each stakeholder creates models using its own perspective, and the collaboration is stimulated by gamification mechanisms embedded in the platform. The PACAS change management process considers the collaboration of various roles, ranging from domain experts, team leaders, builders, all part of the decision making activities, see Figure 2.

Gamification elements have been tailored for each role, taking into account their responsibilities and how they can be incentivized and engaged in using the platform to interact with others. Apart from the avatar, which provides informative messages to the different roles (see Figure 3), the PACAS gamification component considers progressive paths through which a given role can gain points and badges to reach a certain expertise (from novice, up to expert and guru). Specifically, we have devised these three main paths:

- **Challenge Proposer** (a person that identifies the most challenging activities, problems, and the most suitable users, e.g. experts, teams, able to solve that specific problem)
- **Problem Solver** (a person that accept challenges from the avatar or challenge proposers and complete challenges successfully)
- **PACAS Platform Expertise Path** (you progress if you have completed the tour, tutorials and achieved the objectives of each phase in relation to as many as possible change issues)

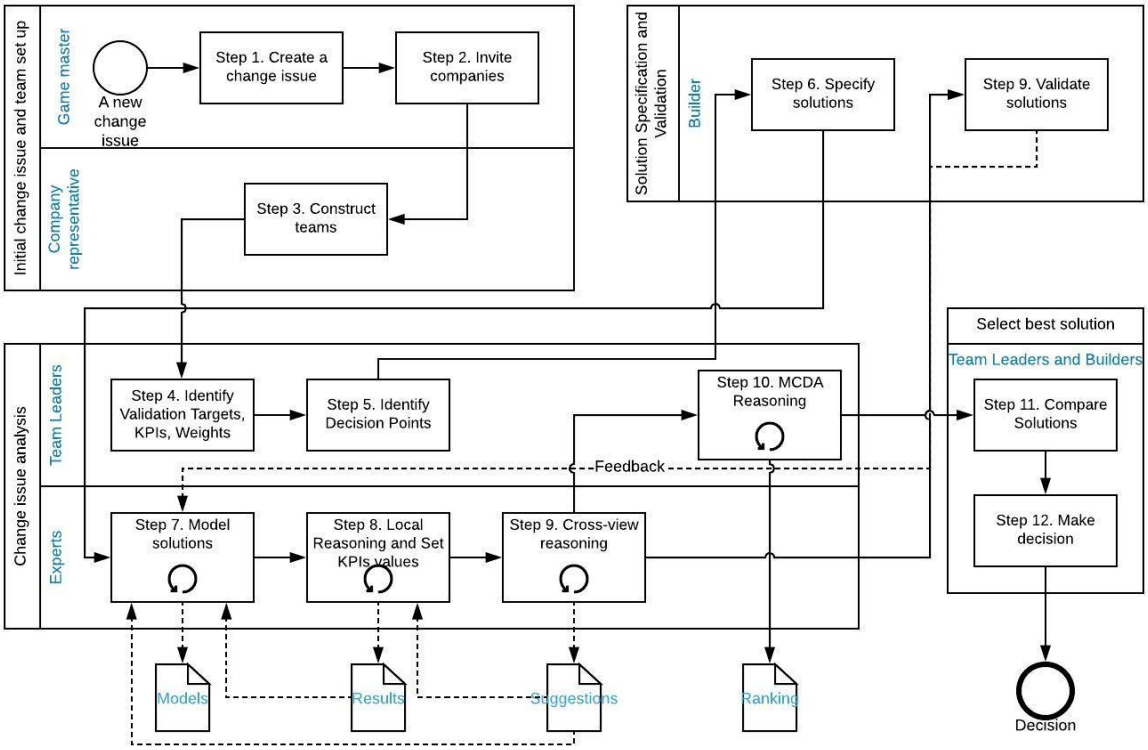

Figure 2: PACAS Change Management Process

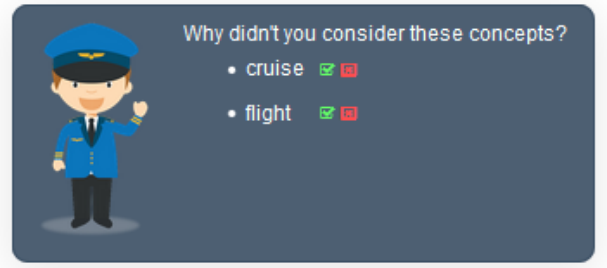

Figure 3: Suggestions displayed by the pilot

An important mechanism is that of challenges (see Figure 4), which are important to foster collaboration: experts may challenge one another to better themselves (e.g., challenges among experts to evaluate the quality of models), as well as their collaboration towards making a decision for a change issue (e.g., game elements to foster actions especially when the user is idle or has not been contributing for some time to the process). As such, challenges help keep the participation to get things done within a certain timeframe. Finally, we have introduced the concept of evaluating challenges, in order to avoid spam or sending useless challenges, while being careful at the same time not to introduce any competition or annoying the users while they are using the platform.

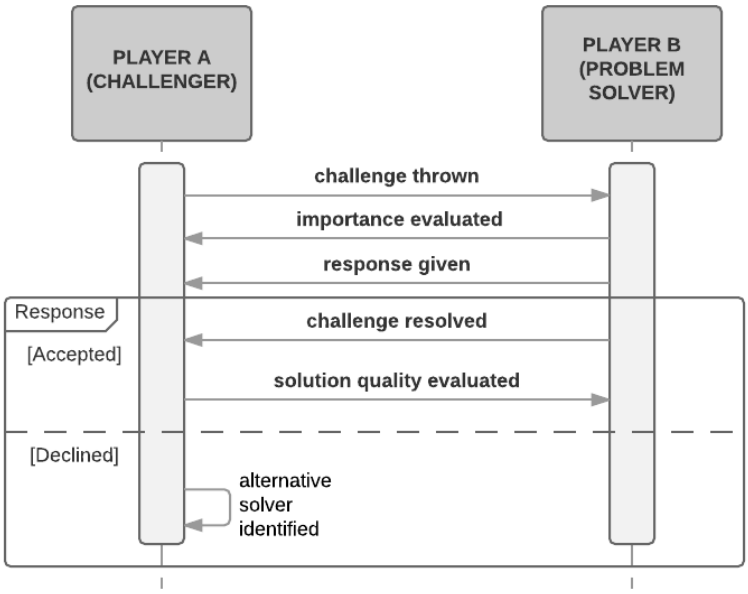

Figure 4: Sequence diagram showing the challenging gamification mechanism

The final release of the PACAS platform fully supports the change management process, the gamification components, as well as the multi-view modelling approach and the shared model concept (WP3), and the automated reasoning support (WP4) which are integrated as external services.

2.3.3 Work Package 3

WP3 has been dedicated to the definition and the development of the modelling concepts used for the multi-view representation of different perspectives. The work was initiated by a review of existing literature related to enterprise architectures, socio-technical modelling, as well as transversal view on modelling changes. Combined with domain expert input, this was the basis for a gap analysis and set of high level macro requirements for the PACAS modelling concepts and views.

This activity was followed by the development of a multi-view modelling approach supporting economic, organisational, safety and security perspectives, along with mechanisms to map meaning across underlying modelling languages and concepts. To support interaction between these views, we defined a common shared meta-model, that is extensible and accommodates different modelling notations and languages, fostering PACAS adoption for other problems and projects not only in the ATM domain, but also in other realities where the interaction of various stakeholders from different areas of expertise is required. Throughout the project, the meta-model has been updated to support the representation of a change issue in the PACAS platform. For each change issue which we evaluate alternative solutions based on key performance indicators set by experts in relation to validation targets. Furthermore, the meta-model lays the foundations for automated reasoning, supporting local reasoning for each modelling notation (STS-ml, FTA, and BIM), cross-view reasoning (providing significant suggestions for impact propagation of changes and performing intelligent cross-view alignment), and last but not least multi-criteria decision analysis.

To illustrate how the modelling reflects the four Key Performance Areas (KPAs) supported by the PACAS platform, namely safety, security, economic, and organisational, we have used an example

scenario from the on-going Sectorless / flight centred ATC project. For each KPA, models such as fault tree, the socio-technical security modelling language, cost and revenues table as well as BIM modelling language are tied together.

2.3.4 Work Package 4

The activities carried out as part of WP4 focussed on the automated reasoning mechanisms that have been included in the PACAS platform to support the various users (in particular, modellers and experts) in their collaboration toward identifying suitable solutions for the change issues that are discussed through the platform (Objective 3 of the project).

In particular, two families of reasoning mechanisms have been developed:

- *Alignment between different models*. In PACAS, different experts construct models to analyse solutions from their own perspective: safety, security, organizational, economic, etc. When a team of experts makes a significant change in a model, such change is automatically analysed by the reasoning techniques of WP4 (Intelligent Cross-View Alignment and Change Impact Propagation) that deliver suggestions to the other modellers on what concepts they may consider to refine and improve their models. The key enablers of these techniques are algorithms from natural language processing and the use of the AIRM domain ontology for air traffic management. Figure 5 shows an example of the type of feedback.

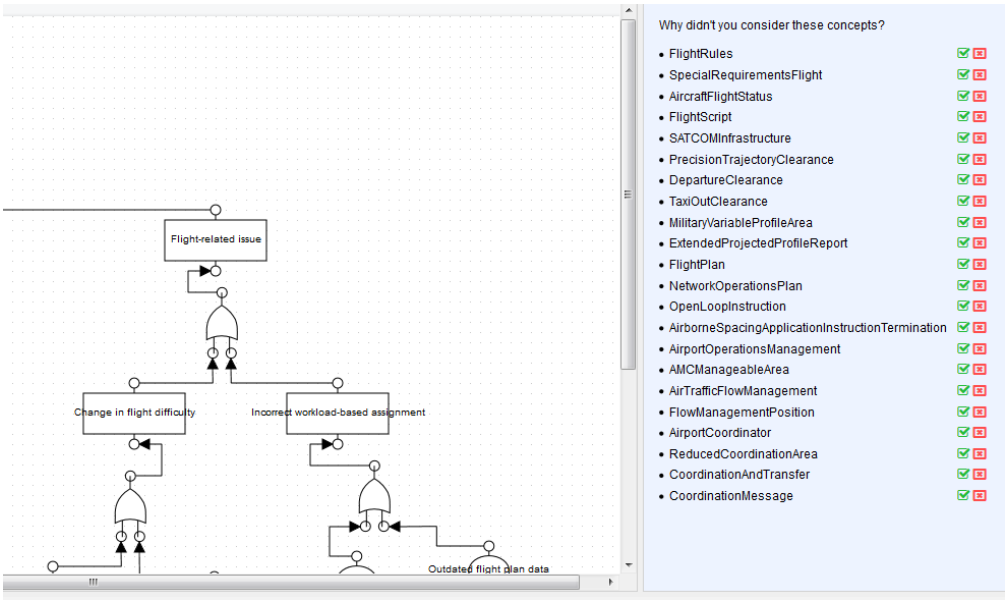

Figure 5: The Intelligent Cross-View Alignment provides suggestions to the safety modeller

- *Computer-supported decision making*. Among the solutions that are analysed by the ATM experts, it is inevitably hard to elect a clear winner, that is, a solution that is better than all the other solutions from each perspective (safety, security, etc.). The PACAS reasoning techniques come to help. We have adapted and implemented techniques from the multi-criteria decision-making literature that combine the different perspectives in a quantitative manner and deliver a ranking of the solutions. Furthermore, to facilitate the understanding

and to allow human decision makers to interpret the results, the outputs of this technique are visualized using a radar chart. Figure 6 illustrates this type of output.

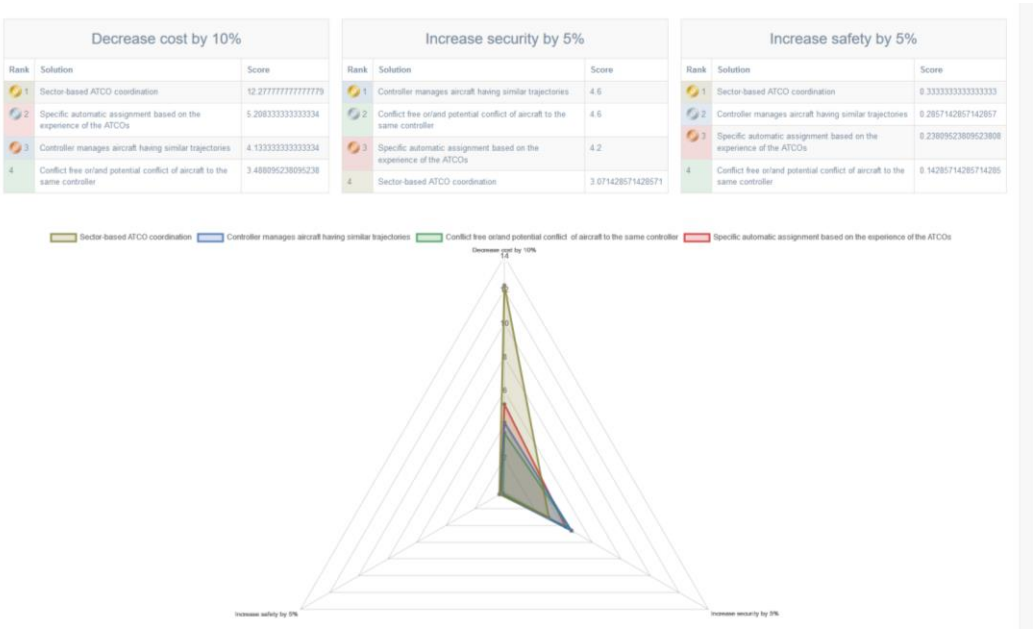

Figure 6: Supporting decision makers in their comparison of the alternative solutions

2.3.5 Work Package 5

The main efforts in this WP were the verification of PACAS methodology and its platform through the use of a case study which was suggested by the Advisory board members and developed thanks to their continued participation. Indeed, one of the pillars of the PACAS project was the end-to-end inclusion of the AB members already during the design and validation phases. This feature of the project was already recognised from the AB members during the preliminary and the first Validation Workshops a key strength point of PACAS with respect to the so called “V shaped” project scheme, that includes the stakeholders only at requirements and final validation stages.
For dealing with this end-to-end inclusion of the AB members into the project, the implementation and validation of the whole PACAS concept was fractioned into a number of sub-goals, or *gates*, to be achieved before proceeding with the further steps of the project. The project was therefore divided into 3 main phases, comprised of four gates to be achieved:

a) ***Phase 1:*** *State of art,* gap analysis and needs elicitation => **Gate 1:** *Requirements definition*
b) ***Phase 2:*** actual work *Activity,* design, development and implementation => **Gate 2:** Use Case and *Scenario definition*, **Gate 3:** *Platform design*.
c) ***Phase 3:*** *Validation* and collection of AB members’ feedback => **Gate 4:** *Final validation*

It is important to notice that each gate, as represented in the external cycle of Figure 7, is the necessary enabler for the following phase.

Such a 3-phase cycle (*State of Art/Activity/Validation*) is repeated, in a fractal fashion, for each goal, or into the evidence of the necessity to start over the same phase, making a further iteration of the smaller cycle in order to meet the AB members’ comments (see the smaller cycle in Figure 7).

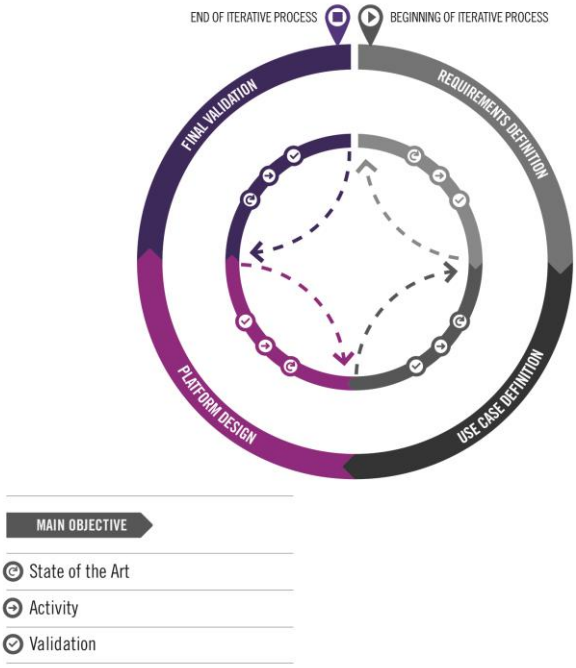

Figure 7: The iterative process of PACAS

Essentially, PACAS made an extensive use of the external AB of domain stakeholders during the whole project. Their key roles helped design and validate both the *methodology* and *platform* and supported all the phases of the project. Indeed, the composition of the group and their specific competencies needed to be carefully planned and tailored on the PACAS necessities and objectives. So, for the PACAS Consortium, the *opinion of the AB was assumed to be always correct*, representative of the whole ATM domain, and complete (e.g., the needs identified by the AB members are taken as representative of the real needs of the domain). Moreover, *validation was based on expert opinion of the AB members*. In particular, we needed to evaluate if decisions taken by using the PACAS process and platform were correct and useful in order to assess the value added to the decision/decision process by PACAS. As far as scalability and applicability are concerned, we used the evaluation of AB members. Furthermore, *the analysis of the system under study was limited to the portion of the ATM* world represented by the selected use case. This was essential to limit the extent of the analysis at a manageable size[1]. As final remark, the *scope of the PACAS validation* was not to corroborate the selected use case but use it as an illustrative example, a means, for *demonstrating the PACAS methodology and enhancing the platform*.

All the performed activities and related validation workshops are illustrated in the following picture (please refer to D5.1 and D5.2 for any further details).

[1] This assumption has no influence on the validation as long as any comparison is done with models considering the same portion of the ATM world

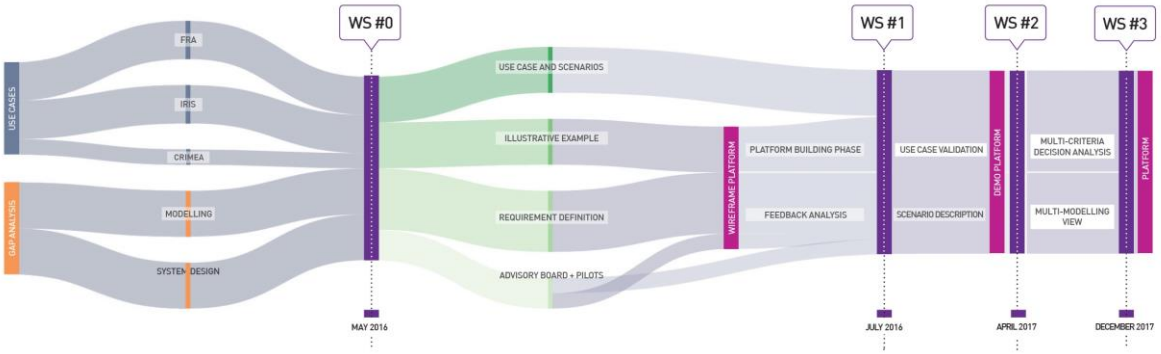

Figure 8: Activities flow and Validation Workshops

2.3.6 Work Package 6

The tasks in the WP6 have been dedicated to the project communication and dissemination policy and strategy, definition objectives for that, target groups, timeline, metrics, resources and roles, key messages and actions and channels for dissemination. Moreover, some efforts have been made towards development of the project website with all its attributes.
The tasks have also considered the exploitation activities, through definition of the exploitation plan (EP), that had gathered the objectives of the project, the main outcomes (results), to whom the project was directed and what activities should had been developed according to that view. In addition, it established the control mechanisms to ensure that the pursued objectives of the EP are accomplished. There had been also defined the Intellectual Property Rights Management (IPRM) and the actions to be carried out with regard. The initial steps for establishing the IP Directory had been carried out. This document has been updated during the lifetime of the project to include the IP Directory at the end.
Finally, the EP has established the exploitation strategy for this project and the exploitation objectives. It defined exploitation activities to reach those objectives, and in addition, quantitative and qualitative monitor metrics. The analysis of the impact of the different activities had been carried out. The market identification complementing the one conducted in the EP has been also conducted. This extension of the market identification aimed at recognizing potential markets that might directly benefit from an application of the PACAS platform, augmenting the visibility and sustainability of the project.

2.3.7 Work Package 7

This WP defined the procedures followed by the PACAS Consortium to ensure compliance with the ethics requirements related to:

- Human participants to the Validation activities
- Protection of Personal Data – Data collection
- Protection of Personal Data – Storage, protection and retention of data

In order to carefully capture and be in line with these requirements, we have studied the General Data Protection Regulation (GDPR) that will be enforced from May 2018, so that the information and data analysed in PACAS comply with the privacy regulation even after the end of the project.

2.4 Key Project Results

Change management process. The change management process takes into account the team and group dynamics when participating in a long decision-making process, dealing with a change issue. Participatory decision-making is of particular importance, for it helps explore more perspectives and a larger set of alternatives, by involving different experts who can analyse the problem from their area of expertise. We have customized the process to reflect the roles from the ATM domain that are involved in a decision-making activity, to allow for an easier adoption as part of ongoing and future projects.

Gamification. The gamification elements proposed in PACAS take into account a characterization of the roles involved in the decision-making process, and although the ATM domain stakeholders part of the advisory board are not representative of the whole domain, still we have shaped the game mechanics and elements so that they may help foster collaboration and keep engaged a wider audience representative of the roles in PACAS. Psychological and organizational factors are also taken into account, such as group dynamics, to shape elements such as paths and challenges, which are crucial especially in a long decision-making process. We have refined these to make them more professional, and this is a first step towards the application to real work settings.

Modelling. The multi-view modelling approach offered in PACAS does not only facilitate the work of different experts who use different modelling languages to analyse a change from their perspective, but also provides support so they can communicate and have a common understanding of the problem, without speaking one another's language. We provide local reasoning techniques, in particular for the security KPA, to allow further improvements of the models before even interacting with other teams for the other KPAs. The mapping done at the conceptual and instance level, is at the basis for the automated reasoning techniques for cross-view alignment and change impact propagation. Nevertheless, the multi-view modelling approach is extensible and it can in the future support the integration of new KPAs and their corresponding modelling languages or notations.

Last but not least, the shared model is an important concept in that it allows a common representation and understanding of the status of the change issue, and supports the humans in the decision-making process, having all the facts captured throughout the models visualized in a single representation.

Automated reasoning. First, the use of natural language processing techniques to help the alignment among the models created by different teams is a key result of the PACAS project. This is a novel approach that is largely unexplored in the literature. We could build this technique for the air traffic management domain thanks to the existence of robust, well-established domain taxonomies such as the AIRM reference model. Second, the application of multi-criteria decision-making algorithms and their illustration through visualization mechanisms is a first step toward a more rationale-based decision making process in the field.

Domain stakeholder involvement at every step. We deem the end-to-end inclusion of ATM domain stakeholders as crucial to the outcomes reached in PACAS. Although this might not be seen as an outcome, it has been a key driver to shape the aforementioned key project results. Indeed, the ATM domain stakeholders that composed our advisory board, has not only served the role of validating PACAS but has been an integral part of refining the requirements for the PACAS components at each validation activity.

2.5 Technical Deliverables

Reference	Title	Delivery Date[2]	Dissemination Level[3]
	Description		
D1.1	Project Management Plan	31/03/2016	Confidential
This document presents the Project Management Plan (PMP) that complements the project information provided in the Grant Agreement and its Annex I - Description of Action, integrating in particular more detailed procedures, briefly describing the Communication and Dissemination Plans, addressing the Ethics Requirements and implementing any additional refinement agreed at the Kick-off meeting.			
D1.6	Publishable Final Project Report	21/02/2018	Public
This report is the final publishable report, the current document, which synthesizes the objectives and outcomes of PACAS, while relating our achievements to the operational context and the SESAR programme.			
D2.1	Gap analysis of existing work in large-scale systems design		Public
This deliverable proposes a thorough review of the existing literature to define a solid baseline for the project, and it identifies a number of requirements for the PACAS decision-making process gaps by reviewing the literature and by gathering an initial set of needs from domain stakeholders as well as from past experience of the consortium within this domain.			
D2.2	First release of the platform and guidelines		Public
This deliverable presents the PACAS platform in a mock-up prototype that through an illustrative example shows the participatory change management process. We present the technical platform through architectural and component diagrams, followed by a set of initial guidelines to be followed when interacting over and with the platform; these guidelines are the basis for the PACAS participatory decision-making process for the ATM domain.			
D2.3	Second major release of the platform and guidelines		Public
This deliverable presents the second major release of the PACAS platform, a working prototype based on web technology named “PACAS web platform”. The deliverable describes a refined design of the platform, including a refined version of the change management process with the definition of the roles involved in its execution, and the definition of the game elements implemented in the platform.			

[2] Delivery date of latest edition

[3] Public or Confidential

The deliverable also describes the relevant updates of the architecture, such as the integration of the automated reasoning services, and presents the PACAS web platform in form of a manual based on the change management process.

D2.4	Final report		Public

This deliverable presents the final release of the PACAS platform and serves as a report on the process and platform. In addition, the deliverable is intended to be used by users as documentation. This final version is the result of several iterations and validation workshops with the advisory board organized throughout the project. With the aid of illustrative examples from the ongoing sectorless / flight centred ATC project, the advisory board has appreciated the richness of the PACAS platform presented in the final validation workshop. The main takeaways are: (i) the platform has great potential in supporting decision-making, (ii) gamification mechanisms are useful in keeping people engaged after the face-to-face meetings and the PACAS platform can help keep track of the progresses; (iii) automated reasoning techniques are key to support the collaboration among experts, both by providing suggestions and by summarizing the results of the trade-off analysis; and (iv) the shared model of a change issue fosters fruitful discussions among different experts who can collaboratively explore the impacts of the proposed solutions from each perspective.

D3.1	Gap analysis of existing modelling methodologies for the ATM domain and requirements elicitation		Public

This deliverable presents a review of existing literature related to enterprise architectures, socio-technical modelling, and stakeholder perspectives as PACAS modelling views, as well as transversal view on resilience and general aspects of modelling changes in particular. Further, the deliverable includes domain expert input on current practices and challenges related to modelling in the ATM domain. These inputs found the basis of a gap analysis and set of high level macro requirements for the PACAS modelling concepts and views, to direct further work in the PACAS project.

D3.2	First release of the Modelling proof of concept		Public

This deliverable presents the first modelling proof-of-concept, that is, the initial proposal of the PACAS modelling views representing the four stakeholder perspectives (security, safety, economic, organisational). This first proposal is the result of several internal iterations and interactions within the consortium, taking into account the results of the gap analysis in D3.1 including the feedback received by the advisory board members during the first PACAS validation workshop. The current proof-of-concept took its present shape also as a result of the feedback obtained by the project officers during the project meeting in Utrecht on the 25th of October 2016.

D3.3	Modelling language meta model		Public

This deliverable presents an updated version of the PACAS meta-model that was presented in Deliverable 3.2. This update is quite important in that it supports the representation of a change issue in the PACAS platform, and how we support decision making, by analysing a given change issue through decision points, for each of which we evaluate alternative solutions based on key performance indicators set by experts in relation to validation targets. Most importantly, we present the machine-based reasoning supported by the updated meta-model, both reporting on (i) the local reasoning techniques supported for each key performance area, namely security, safety and economic and organizational, and (ii) the meta-model links we establish in order to support cross-view impact propagation of changes and multi-criteria decision-making. We finally describe a preliminary modelling notation that is used to provide the stakeholders with an overview of change issues, followed by an application of this notion to the ongoing Sectorless change issue.

D3.4	Final release of the Modelling proof- of -concept		Public

This deliverable presents the final modelling proof-of-concept, representing the four Key Performance Areas

(KPAs) supported by the PACAS platform, namely safety, security, economic, and organisational. We detail the modelling languages and notations used by default in PACAS, such as fault tree, the socio-technical security modelling language, cost and revenues table as well as BIM modelling language for each KPA respectively, illustrating them with an excerpt scenario from the ongoing Sectorless / flight centred ATC project. This final version is the result of several internal iterations and interactions within the consortium as well as validation workshops with the advisory board organized throughout the project. This version was presented to the advisory board at the final validation workshop. The AB has appreciated the richness of the PACAS platform with respect to capturing and analysing the complex organizational domain of ATM (especially through STS-ml modelling and local reasoning). Finally, the shared model of a change issue has quite some potential in that it fosters fruitful discussions among different experts who can collaboratively explore the impacts of the proposed solutions from each perspective.			
D4.1	Gap analysis of existing reasoning techniques and requirements for the ATM participatory architectural design		Public
This deliverable identifies the gap between the domain stakeholders' needs (the PACAS advisory board and past experience by the partners) and the state-of-the-art reasoning techniques identified from a literature review. The outcome of this deliverable is a gap analysis finalized with the identification of requirements for the PACAS reasoning support.			
D4.2	First release of the reasoning proof -of -concept		Public
This document reports on the consortium's efforts on Intelligent Cross-view Alignment (ICVA), an analysis of models that is based on algorithms from the natural language processing (NLP) domain. ICVA suggests missing concepts to a model from a common air traffic management vocabulary based on the concepts present in other models. The deliverable also presents two other reasoning mechanisms for the project: (i) an NLP-based dashboard for the modellers and (ii) a multi-objective reasoning solution to help the decision making process to select the final solution.			
D4.3	Final release of the reasoning proof -of -concept		Public
This deliverable introduces two new services. The first service is the PACAS *multi-criteria decision-analysis service*, which automatically ranks alternative solutions based on decision criteria set by experts using well-known multi-criteria decision analysis techniques such as the weighted sum model, the weighted product model, and TOPSIS. The second service is the *change impact propagation service* that highlights elements in a model that are likely to be affected by the changes in other models; such service relies on computational linguistics algorithms that compare the labels of the model elements, and makes use of a domain taxonomy to identify domain-specific terms.			
D5.1	Concept, Scenarios and Validation Plan	23/12/2016	Public
This document provides a detailed description of the PACAS concept, explains the validation strategy as well as its subjects, objectives and criteria (i.e., what is to be validated in PACAS, what we want to test, and how we plan to test it) and provides the schedule for the Validation Workshops and their content. It also offers a description of the selected case study.			
D5.2	Validation Report	21/02/2018	Public
This document provides a comprehensive description of the PACAS validation activities and of the 4 associated Validation Workshops and their content. Furthermore, starting from the results of these Workshops, it reports specific recommendations for each technical work package, which will be used for the following exploitation and dissemination actions.			
D6.1	Communication and dissemination plan	06/04/2016	Public
This document presents the PACAS Dissemination Plan developed to promote the project and its results properly. The document illustrates the dissemination goals, the overall dissemination strategy and the needed			

dissemination activities. It also identifies the dissemination actions planned for the near future.			
D6.2	Exploitation plan	29/08/2016	Public
This document presents the PACAS Exploitation Plan developed to promote the project and its results accurately. PACAS takes adequate measures to maximize the impact of the results; specific activities are chosen to ensure fitness with the expected Technological Readiness Level of the call, which is TRL 2. It means that technology concept and/or application have been formulated. In particular, potential application of the basis (technological) principles are identified, including their technological concept. Also the first manufacturing principles are explored, as well as possible markets identified. A small research team is established to facilitate assessment of technological feasibility. In view of that, the impact will be mostly determined by the concepts that originate from PACAS, rather than fully-fledged prototypes.			
D6.3	Intermediate Communication and Dissemination report	28/02/2017	Public
Dissemination represents one of the core activities of the PACAS project. Our dissemination strategy is based on the identification of groups of stakeholders who may be interested in the project findings, and on the personalization of the communication message for the stakeholder characteristics in terms of content, style and information support. So, this document aims at reporting the different communication and dissemination actions carried out along year 2016 of the PACAS project. The main communication and dissemination actions carried out for that period are (i) Dissemination towards the SESAR and H2020 programs, with the preparation of a PACAS project presentation; (ii) Dissemination towards General Public, with PACAS project website, social networks (both LinkedIn and Twitter) and press releases; (iii) Dissemination towards Scientific Community, with publication and presentation of research work elaborated to contribute to PACAS project; (iv) Dissemination towards Education, with lessons/courses dedicated to local students in secondary and higher education in order to involve them in the project topics; (v) Dissemination towards Advisory Board, with validation workshops and related materials to iteratively and continuously check PACAS progress.			
D6.4	Communication and dissemination report	19/02/2018	Public
This document is complementary to the Intermediate one and it reports the different communication and dissemination actions carried out along the second year of the PACAS project.			
D6.5	Roadmap for the exploitation	21/02/2018	Public
This document presents the PACAS Exploitation Roadmap describing how the consortium intends to use the PACAS results for their exploitation at academic and commercial purposes. It includes information about the exploitation process applied in the project, the project results identified as exploitable, the target stakeholders of the exploitation activities, SWOT analysis, IPR management and details on both individual and joint exploitation strategies foreseen by the partners in the next 4 years. Finally, a roadmap for the exploitation is offered, concerning both individual and joint exploitation initiatives.			
D7.1	POPD - Requirement No. 3		Confidential
The deliverable presents the procedures followed by the PACAS Consortium to ensure compliance with the 'ethics requirements' set out in WP7. Detailed information is provided on the procedures that will be implemented for data collection, storage, protection, retention and destruction and confirmation that they comply with national and EU legislation.			
D7.2	POPD - Requirement No. 2		Confidential
The deliverable presents the procedures followed by the PACAS Consortium to ensure compliance with the ethics requirement n.2 set out in WP7. Detailed information must be provided on the informed consent procedures that will be implemented.			
D7.3	POPD - Requirement No. 1		Confidential
The deliverable presents the procedures followed by the PACAS Consortium to ensure compliance			

	with the ethics requirement n.1 set out in WP7. Detailed information must be provided on the informed consent procedures that will be implemented.

Table 1: Project Deliverables

3 Links to SESAR Programme

3.1 Contribution to the ATM Master Plan

The objective of SESAR is to modernise European ATM by defining, developing and delivering new or improved technologies and procedures namely SESAR Solutions through funding projects. Indeed, SESAR's vision builds on the notion of trajectory-based operations' and relies on the provision of Air Navigation Services (ANS) in support of the execution of the business or mission trajectory — meaning that aircraft can fly their preferred trajectories **without being constrained by airspace configurations**.

This vision is enabled by a progressive increase of the level of automation support, the implementation of virtualisation technologies as well as the use of standardised and interoperable systems. The system infrastructure will gradually evolve with digitalisation technology, allowing Air Navigation Service Providers (ANSPs), irrespective of national borders, to plug in their operations where needed, supported by a range of information services. Airports will be fully integrated into the ATM network level, which will facilitate and optimise airspace user operations.

Going beyond 2035 towards 2050, performance-based operations will be implemented across Europe, with multiple options envisaged, such as **seamless coordination between ANSPs** or full **end-to-end ANS provided at network level**. Furthermore, it is widely recognised that to increase performance, ATM modernisation should look at the flight as a whole, within a flow and network context, rather than segmented portions of its trajectory, as is the case today. With this in mind, the vision will be realised across the entire ATM system, offering improvements at every stage of the flight.

One major challenge is that the impact of the envisioned change is hard to understand clearly, because it is different when we consider different aspects of the ATM system such as safety, security, organisation of work, economy, etc. Comparisons between alternatives are difficult to perform because, typically, no obvious "best" alternative emerges (one given solution fares better relative to some performance areas, but worst relative to others). On the contrary, the selection of a "best" alternative requires the consideration of potential limitations and trade-offs.

Furthermore, SESAR aims to meet the business needs of a range of ATM stakeholders, from airports big and small and ANSPs, to airspace users of all categories, the military and the Network Manager. The related decision-making process is hindered by the fact that these different stakeholders have various and sometimes conflicting interests, they represent different perspectives and have dissimilar expertise (e.g. safety, security and so on), belong to different departments or organisations, are located in different countries, etc. So, the future and optimised ATM network must be robust and resilient and its design as well as its strategic evolution should be supported by **dynamic and collaborative mechanism/tool**. This will allow for a **common, updated, consistent and accurate plan that provides reference information to all planning and executing ATM actors**.

PACAS claims for an increased importance of participatory and collaborative tools on the decision-making process relying on the end-to-end inclusion of ATM domain stakeholders through gamification. Its novel participatory design process to handle change management is based on the provision of multiple views as well as the representation and analysis of multiple objectives, namely

those related to economical, organizational, security, and safety concerns. Due to its holistic approach, PACAS cannot be only related to a specific Operational Improvements but in its future developments, it might be contribute to several SESAR Solutions such as:

- **Solution PJ.07-01** — *AU Processes for Trajectory Definition*: "Airspace Users' Processes for Trajectory Definition refers to the development of FOC related processes for the management and update of the Shared Business Trajectory to achieve the full integration of FOCs in the ATM Network processes, increase FOCs role with regard to the Trajectory Management in future ATM and Investigate the impact of such integration on all concerned ATM actors performance. The processes respond to the need to accommodate individual airspace users' business needs and priorities without compromising optimum ATM system outcome and the performances of all stakeholders";
- **Solution PJ.09-01** — *Network Prediction and Performance:* "Network Prediction and Performance relies on shared situational awareness with respect to demand, capacity and performance and has an impact on regional, sub-regional and local demand and capacity balancing (DCB) processes. It consists of improved traffic and demand forecast based on SBT and the computation of confidence indexes. Prediction of DCB constraints and complexity issues will be based on the definition of metrics and algorithms for prediction, detection and assessment of traffic complexity, thus improving the accuracy and credibility of the diagnosis and awareness of hotspots. Network Operations will be monitored through Network Performance KPA/KPI while a Network impact assessment will analyse trade-offs and facilitate collaborative decision making processes*";*
- **Solution PJ.09-03** — *Collaborative Network Management Functions*: "Collaborative Network Management Functions allow for network management based on transparency, performance targets and agreed control mechanisms. The solution enables a real-time visualisation of the evolving AOP/NOP planning environment (such as demand pattern and capacity bottlenecks) to support airspace user and local planning activities. Network Operations planning and execution is managed by an agreed set of rules and procedures (including what-if), guiding subsidiary DCB and UDPP measures under consideration of trade-offs and network performance targets. Collaborative 4D constraints management integrates AUs priorities and preferences, reconciliation of DCB measures with Airports, ACCs, AU and NM, relying on the Multiple Constraints Resolver process";
- **Solution PJ.10-01b** — *Flight Centred ATC*: "Flight Centred ATC sees the provision of ground-based automated support for managing separation provision across several sectors in order to enable larger sectors to be used. Rather than managing the entire traffic within a given sector. With this solution ATC is responsible for a certain number of aircraft throughout their flight segment within a larger airspace or along flows of traffic".

Obviously, all these solutions are directly related to Operational Improvements and PACAS might provide some contribution once it will reach a higher maturity level. The following table reports some examples linked to different solutions and OIs.

Code	Name	Project contribution	Maturity at project start	Maturity at project end
AOM-0805	Collaborative Airspace Configuration	The OI aims at activating airspace configurations	TRL0	TRL2

Code	Name	Project contribution	Maturity at project start	Maturity at project end
		through integrated collaborative decision making processes at national, sub-regional and regional levels. Procedures and system support tools shall be defined to enable to manage the airspace configurations as a continuum to meet the users' expectations. The project offers a collaborative platform for supporting this process		
DCB-0212	Network Performance Assessment for Distributed Network Operation	The project has developed a platform for "automatically" evaluate the impacts that a change may have on the other elements of the system. This facilitates the collaborative decision making processes and help all the involved stakeholders in reaching an agreement	TRL0	TRL2
DCB-0103-B	Collaborative	The main	TRL0	TRL2

Code	Name	Project contribution	Maturity at project start	Maturity at project end
	NOP for Step 2	objective of this OI is to move to performance-driven actions, and anticipate as much as possible, providing time to develop, organise and coordinate complex decisions. This will be facilitated by better quality information, and increased interactivity between the Network Manager and stakeholders. PACAS through its platform can offer a collaborative tool.		
CM-0200-B	Flight-centred ATC in Non-Geographically-Constrained, Low complexity En-Route environment	This OI has been preliminary explored by PACAS through its case study. The developed models and initial findings may be further improved by involving other Service Providers that may have different operational needs	TRL0	TRL2

Table 2: Project Maturity

3.2 Maturity Assessment

ID	Criteria	Satisfaction	Rationale - Link to deliverables - Comments
TRL-1.1	Has the ATM problem/challenge/need(s) that innovation would contribute to solve been identified? Where does the problem lie?	Achieved	Air Traffic Management (ATM) systems are complex systems of systems. Understanding all possible consequences of a design decision in an ATM system is a challenge due to the complexity of ATM systems and the existence of tight interdependencies within the ATM architecture. Knowing the implications of change(s) over the whole system is crucial to support decision-making, while making sure that the ATM system does not suffer from any issues with respect to functionality, safety, security, performance, cost efficiency, or other desired characteristics of a well-functioning ATM system. Given that decision-making involves the consideration of more high-level objectives, the change management process should involve multiple ATM domain stakeholders, one for each given objective, in order to explore a vast space of alternatives and agreeing on optimal solutions. It becomes, thus, crucial the active participation of stakeholders. However, given the variety of experts, their different areas of expertise, as well as their geographical distribution, participatory change management requires user engagement and tools to support and facilitate the work of experts along their interaction. To address the first concern, in recent years, gamification is broadly used as a tool to engage participation with the help of elements, such as leader-boards or challenges between users. On the other hand, a multi-perspective, model-based approach provides important benefits in that: (i) it allows analyzing individual perspectives without the need of a holistic representation; (ii) it handles complexity through automated reasoning techniques in a transparent way to find optimal solutions as a trade-off among different objectives. In its two years, PACAS has made the following technical contributions to tackle the aforementioned problems: 1- A novel gamified change management process that relies on the end-to-end inclusion of ATM domain experts, ranging from decision-makers (managers and team leaders) to analysts (experts) 2- Refined modelling notations for each KPA (security, safety, economic and organizational), which are at the basis of the multi-view modelling approach, and a shared model that apart from providing an overview of the status of the change under analysis, provides great benefits to an informed decision-making process

ID	Criteria	Satisfaction	Rationale - Link to deliverables - Comments
			3- A range of automated reasoning techniques spanning from local reasoning performed within a single modelling environment, to those across views that are crucial for facilitating the work of modelers (intelligent cross-view alignment – ICVA and change impact propagation – CIP) and for supporting multi-criteria decision making (three different techniques for MCDA) Through the end-to-end inclusion of ATM domain stakeholders, PACAS has not only validated the PACAS concept, but it has defined and refined the requirements for PACAS process and platform in an iterative fashion until their final release.
TRL-1.2	Has the ATM problem/challenge/need(s) been quantified?	Not Applicable	
TRL-1.3	Are potential weaknesses and constraints identified related to the exploratory topic/solution under research? - The problem/challenge/need under research may be bound by certain constraints, such as time, geographical location, environment, cost of solutions or others.	Partial – Non Blocking	The PACAS concept has been developed with the help of case studies, as reported in the Validation Plan (D5.1) and developing an illustrative change management case with the help of the Advisory Board members. To bridge in the gap of the knowledge of the PACAS consortium of the ATM and SESAR ongoing projects, we assume the knowledge of the AB members to be representative and always right.
TRL-1.4	Has the concept/technology under research defined, described, analysed and reported?	Achieved	We have described the development of the PACAS process and platform throught the various deliverables of WP2, starting from gap analysis reported in "D2.1 Gap analysis of existing work in large-scale systems design", to the first release in "D2.2 First release of the platform and guidelines", the second in to "D2.3 Second major release of the platform and guidelines", till "D2.4 Final report" that does not only provide the final version of the PACAS process and platform, but also provides a user guide in the form of a manual.

ID	Criteria	Satisfaction	Rationale - Link to deliverables - Comments
TRL-1.5	Do fundamental research results show contribution to the Programme strategic objectives e.g. performance ambitions identified at the ATM MP Level?	Partial – Non Blocking	The PACAS change management process lays the ground to support whether changes at strategic level can help or inhibit the achievement of performance ambitions identified at the ATM master plan. In particular, we focus on validation targets related to four key performance areas, namely security, safety, economic and organizational. However, further research activities are needed for developing a higher TRL platform that can support other performance ambitions, but also go down to operational levels, and take into account the KPIs from simulations.
TRL-1.6	Do the obtained results from the fundamental research activities suggest innovative solutions/concepts/ capabilities? - What are these new capabilities? - Can they be technically implemented?	Partial – Non Blocking	Partial because the platform and its components (e.g., models, automated reasoning - TRL2) are not implemented and/or integrated within EATMA. PACAS is an exploratory research project and its outcomes offer support for decision making, while allowing the collaboration of more ATM domain experts analysing change from their area of expertise. The gamified PACAS process can be used to not only support the work of the various experts, who might work from different locations and using different languages and terminology, but also can be used to keep track of a given change issue, and offer support for such long activity such as decision-making for change management. As far as implementation is concerned, we understand this in the context of EATMA, PACAS contributes to improve the strategic layer, but it can be integrated with other projects that go down to the for instance the operational layer.
TRL-1.7	Are physical laws and assumptions used in the innovative concept/technology defined?	Achieved	Assumptions and limitations of a validation activity are thus necessary and unavoidable. They are often necessary to provide a frame for the evaluation process, but, they can also have a powerful effect on the conclusions of the analysis that should not be underestimated. There are some general assumptions we have made during our validation activities in PACAS: • The opinion of the AB is assumed to be always correct, representative of the whole ATM domain, and complete (e.g., the needs identified by the AB members are taken as representative of the real needs of the domain). Moreover, validation will be based on expert opinion of the AB members. In particular, we need to evaluate if decisions taken by using the PACAS process and platform are correct and useful in order to assess the value added to the decision/decision process by PACAS. As far as scalability and applicability are concerned, we use the evaluation of AB members • The analysis of the system under study can be limited to the portion of the ATM world represented by the use case we will apply. This is essential to limit the extent of the analysis at a manageable size. This

ID	Criteria	Satisfaction	Rationale - Link to deliverables - Comments
			assumption has no influence on the validation as long as any comparison is done with models considering the same portion of the ATM world.
TRL-1.8	Have the potential strengths and benefits identified? Have the potential limitations and disbenefits identified? - Qualitative assessment on potential benefits/limitations. This will help orientate future validation activities. It may be that quantitative information already exists, in which case it should be used if possible.	Achieved	PACAS is the result of an iterative development process that involves the end-to-end inclusion of ATM domain experts. Key strength points are the support for the collaboration of different experts with different expertise through multi-view modelling, engagement via gamification and support decision-making with automated reasoning techniques. Through the validation activities, some limitations have emerged, such as the difference in languages used in the domain, the need to align terminologies, and acceptance of gamification mechanisms in a real working environments. These are reported in the WP2 and WP5 deliverables.
TRL-1.9	Have Initial scientific observations been reported in technical reports (or journals/conference papers)?	Achieved	The results of PACAS have been reported in several technical reports and papers as described in detail in WP6 deliverables, in particular "D6.1 Communication and Dissemination Plan", "D6.3 Intermediate Communication and dissemination report", and "D6.4 Communication and dissemination report". Furthermore, these activities and papers have been timely reported on the Pacas project website and publicised on different social networks.
TRL-1.10	Have the research hypothesis been formulated and documented?	Achieved	The project objectives are clearly stated in the DoW, and they have been refined and contextualized at each step in achieving the work done in PACAS to deliver all the components, starting from gap analysis to identify requirements, to the process, modelling, gamification, and automated reasoning support. Finally, the validation activities have been guided by clearly defining the research questions and the outcomes to validate. These are transversal to all the WPs, from WP2-WP5.
TRL-1.11	Is there further scientific research possible and necessary in the future?	Achieved	As detailed described in D6.5, further scientific research is necessary as individual and joint exploitation. It is in line with the Exploratory Research principles, fostering the introduction of new scientific, technology innovation and educational benefits to the ATM Community and the integration of Exploratory Research projects into the SESAR mainstream and future SESAR 2020 program as appropriate.

ID	Criteria	Satisfaction	Rationale - Link to deliverables - Comments
			In the case of PACAS, this latter aspect seems particularly suitable as the tools developed by the project (and here discussed as Exploitable Results) have already been tested within SESAR, proving to be potentially useful for supporting the design of new operational concepts and technologies being developed within SESAR. In the framework of the PACAS joint exploitation strategy, it would be then worth exploring the possibility of a follow-up project having the twofold purpose: to improve the PACAS tools and at the same give a support for the developed of selected solution projects
TRL-1.12	Are stakeholder's interested about the technology (customer, funding source, etc.)?	Achieved	The identified stakeholders who have been directly involved in the project, are really interested about the platform and its potential use in the operational environment (please refer to D5.2).

Table 3: ER Fund / AO Research Maturity Assessment

4 Conclusion and Lessons Learned

4.1 Conclusions

The PACAS project has developed a gamified platform to support participatory decision-making for change management. Throughout the journey, the PACAS consortium has acquired a vast amount of domain specific knowledge that was deemed necessary for delivering a more tailored platform. Such knowledge was not easily accessible to the PACAS consortium, but the continuous interaction with AB members and with the POs has helped us in bridging this gap and in gaining insights to the complex world of EATM architecture, aligning our platform with the domain-specific terminology, and in exploiting already available taxonomies and knowledge bases.

The final release of the PACAS platform is the result of design choices taken by the consortium to implement the PACAS web platform, as well as the feedback received from the AB members during the various validation workshops at each release.

4.2 Technical Lessons Learned

From WP1	**Lessons Learned from Project Management**
	Small consortiums with all the consortium members fully engaged in the successful implementation of research objectives creates a friendly atmosphere during brainstorming sessions that foster the identification of most prominent solutions to academic problems. Needless to say, that a small consortium is easy going from the financial and accountability aspects. However, a word of caution must be arisen when technology integration aspects are considered at late stages. These scenarios can force the full team to go over again the technologies implemented. Project management should consider extra efforts in the proper coordination of WP's at technological level, not only considering the outcomes.
From WP 2	**Lessons Learned from Participatory design for ATM architecture change management**
	Consider more techniques for requirements elicitation: in deepening our understanding of the complex ATM world and understanding the requirements for supporting at best change management, we could not talk to end users alone. Instead, we performed an extensive literature review, and analysis of needs from other SESAR projects and existing use cases that deal with managing change. This laid down the path to performing semi-structured interviews with domain stakeholders (AB members) that helped confirm requirements or dispel doubts while eliciting new requirements for the change management platform.

	Provide user incentives for collaboration and engagement: decision-making for change management in ATM systems is a long process involving multiple stakeholders, and it is challenging to have them collaborate and keep them engaged also after potential face-to-face meetings. The use of incentives and psychological factors is crucial in defining the right elements for user engagement. This is at the basis of the gamification mechanisms defined in PACAS. Through the involvement of domain stakeholders we have been able to refine these elements in order to meet at best the expectations of domain experts to foster their collaboration.
	On the platform-development side, **use mock-ups and prototypes**: after the initial problem definition and terminological alignment, it is crucial to involve domain stakeholders into providing feedback and knowhow after seeing and having hands-on sessions with various mock- ups and prototypes of the platform.
	It is worth mentioning that from our experience, an important take away is that although **automated reasoning techniques are crucial to facilitate understanding and support decision-making, they cannot substitute or overcome elements such as human knowledge and social and organizational factors of power and position**, which are part of the organizational culture and structure, and might change the direction of future developments regardless of automated reasoning results. As such, reasoning techniques are a powerful tool to provide the right means and facts to justify and make informed decisions, but the last word remains to the human decision makers.
From WP3	**Lessons learned from development of multi-view modelling and shared model**
	Terminology alignment: PACAS is composed of several partners among universities and companies with different backgrounds. Therefore, it was not easy during the early stage of the requirements elicitation process to have a common understanding of the feedback received from the AB members. Through several iterations, we defined the main concepts to deal with change management, namely, change issue, decision point, solution, KPIs, and validation targets. In addition, the interactions with the POs have helped bridge the gap and align the terminology with that used across SESAR projects.
	Develop different modelling notations per expertise: Models are useful to improve decision processes for change management. A multi-view, model-based approach provides important benefits in that it allows analysing individual perspectives without the need of a holistic representation. For instance, in dealing with safety, safety experts can analyse a series of events (e.g., broadcasting messages to pilots) that may lead to major threats (e.g., spoofing of information or man in the middle attacks). **Separating concerns** helps reduce complexity and focus attention on specific issues, diving deep into the problem and exploring more situations, in order to understand the impacts and repercussions while collaborating with other experts from the same area. The **choice of modelling languages** is also crucial in supporting the work of experts and their collaboration and sharing of results. For instance, to support safety we opted for fault tree analysis since it is widely used in ATM. On the other hand, to analyse economical aspects, we developed a typical financial cost-revenue table with dedicated voices, with which financial experts are familiar.

	Solve conflicts during the process by offering a common representation to keep track of the status of change: when decision-makers have different opinions, choices and preferences from what is suggested by automated reasoning techniques, it is crucial to provide tools that can facilitate their argumentation. The shared model among stakeholders highlights how well new requirements fare with respect to high-level objectives such as cutting down costs, increasing safety and security, etc. This puts decision makers in perspective of realizing the repercussions of their decisions on other perspectives too.
From WP4	**Lessons learned from developing automated reasoning techniques for alignment, impact propagation and multi-criteria decision-making**
	The Intelligent Cross-View Alignment is a promising idea that can be extended and embedded in tools for the enterprise architecture domain, such as the MEGA tool. The main necessary improvements concern the ability for users to customize the type of inputs they receive (how many suggestions? How specific?), and the ability to use specific domain ontologies that refine AIRM for given sub-domains, such as controller assignment.
	The multi-criteria decision making technique has proven to be effective to provide a summary to the human decision makers. Future work should tackle classic problems with these techniques, that is, how to effectively visualize the results and how to facilitate the experts in assessing the quality of a given solution.
	Change impact propagation is a novel technique that has been experimented to a limited extent during the PACAS project. Future projects should evolve this technique and adapt it to state-of-the-practice modelling languages used in ATM design.
From WP5	**Lessons learned from Verification and Validation**
	The **end-to-end inclusion of the AB members** already during the design and validation phases has been one of the pillars of the project. This feature of the project was already recognised from the AB members during the preliminary and the first Validation Workshops a key strength point of PACAS with respect to the so called “V shaped” project scheme, that includes the stakeholders only at requirements and final validation stages.
	The **iterative approach** proposed in the design and development of the platform has been very helpful in the validation processes identifying more easily bugs and problems which have been timely solved
From WP6	**Lessons learned from Dissemination and Exploitation**
	PACAS dissemination strategy was based on the **identification of groups of stakeholders** who may be interested in the project findings, and on the **personalization of the communication message** for the stakeholder characteristics in terms of content, style and information support. This strategy allowed us to customise and adapt the messages for a particular target audience and create different communication channels

	to properly distribute it.
	Among the communication channels it is believed that web and social networks have been the most successful medium to distribute information and updates among particular ATM members that were identified in technical conferences.
	Among the dissemination channels it is acknowledged that technical presentations, workshops and dedicated events have motivated different collectives to ask for more details about the project. Thanks to the involvement of all partners with different expertise, not only the ATM community has been reactive to the PACAS ideas but also the more academic one (e.g. requirements and software engineering, modelling, information science and so on)
	The exploitation plan proposed was very ambitious as well as the TRL. However, it is considered that the excellent results achieved at the prototype level will still require a long journey to pursuit the evolution of the PACAS toolkit within the SESAR framework. The true engagement of consortium members has allowed to identify a clear path for the joint and individual exploitation not only at academic level but also at industrial one.
From WP7	**Lessons Learned from Protection of Personal Data**
	The interaction with AB members through the various validation workshops has required gathering both personal and professional data, as well as their opinions and domain expertise, which has helped shape the development of the PACAS process and platform, along its components. Already in the beginning of the project, we have taken into account the requirements for the protection of personal data as required by the latest European privacy regulation, GDPR.

4.3 Plan for next R&D phase (Next steps)

The implementation and validation of PACAS has unveiled several operational conditions that requires extra research to extend the applicability of PACAS framework. This additional research could be performed both as individual and also as joint exploitation. Indeed, as accurately reported in “D6.5 Roadmap for the exploitation”, regarding the individual exploitation, the PACAS Consortium includes one SME, two Universities and one large independent research organisation. Such different entities also have different exploitation needs and possibilities; therefore, partners’ exploitation paths differ from each other. These paths are based on the individual strategies formulated by the PACAS partners, which could be essentially distinguished in academic and commercial initiatives. The following picture represents the roadmap for the individual exploitation.

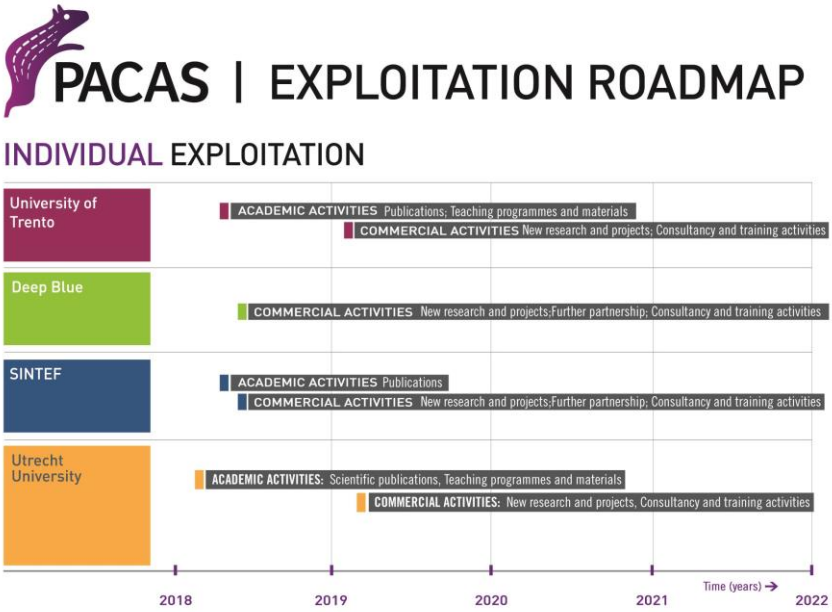

Figure 9: Individual exploitation roadmap

For what concerns the joint exploitation, considering the PACAS tools TRL and the positive feedback received by the AB members, the strategy could be to continue working together on the topic, and to pursuit the evolution of the PACAS platform within the SESAR framework in which it is has been invented. This seems the most effective and practical way to make the outcomes of PACAS evolving and reaching the higher level of maturity that is necessary to seriously consider it as product and ponder possible measures to commercially exploit it.

It is in line with the Exploratory Research principles, fostering the introduction of new scientific, technology innovation and educational benefits to the ATM Community and the integration of Exploratory Research projects into the SESAR mainstream and future SESAR 2020 program as appropriate.

In the case of PACAS, this latter aspect seems particularly suitable as the platform developed by the project has already been tested within SESAR, proving to be potentially useful for supporting the design of new operational concepts and technologies being developed within SESAR. In the framework of the PACAS joint exploitation strategy, it would be then worth exploring the possibility of a follow-up project having the twofold purpose: to improve the PACAS tools and at the same give a support for the developed of selected solution projects.

It could be achieved in a 3-year timeframe (ideally 2019-2021) applying the PACAS platform iteratively to a selected group of three SESAR Solution Projects chosen on the basis of a set of criteria related not only to PACAS needs, but also to projects aims and activities. An initial list of tentative selection criteria emerged from the experience gathered in PACAS includes projects:

- requiring collaborative decision-making among different stakeholders
- having an interest in studying the impact of their solution on the strategic layers considered by PACAS, namely economic, organizational, security, and safety

- having problems of balancing the impacts of specific decisions on the strategic layers considered by PACAS, namely economic, organizational, security, and safety

In this respect, the nature of the solution being studied by the project is not relevant (i.e., whether it concerns the introduction of a new role, new airspace organization concept or new traffic management processes, etc). The key elements in fact to determine if the project is suitable or not for the application of the PACAS results concern its interest in the strategic layers and the need for collaborative decision-making processes.

Each application will aim on the one side to validate, further refine the platform and bring it to a higher level of maturity, and on the other side to practically support the project in the combined analysis of possible implications of specific design options under discussion.

Imagining an iterative process based on 3 cycles of design and validation and assuming that the TRL of the toolkit will proportionally increase, at the end of the follow up project we (as ATM Community) could rely on a robust and mature platform (TRL6), ready to be put at disposal of all SESAR Solution projects and of the ATM Community (as represented in the following picture).

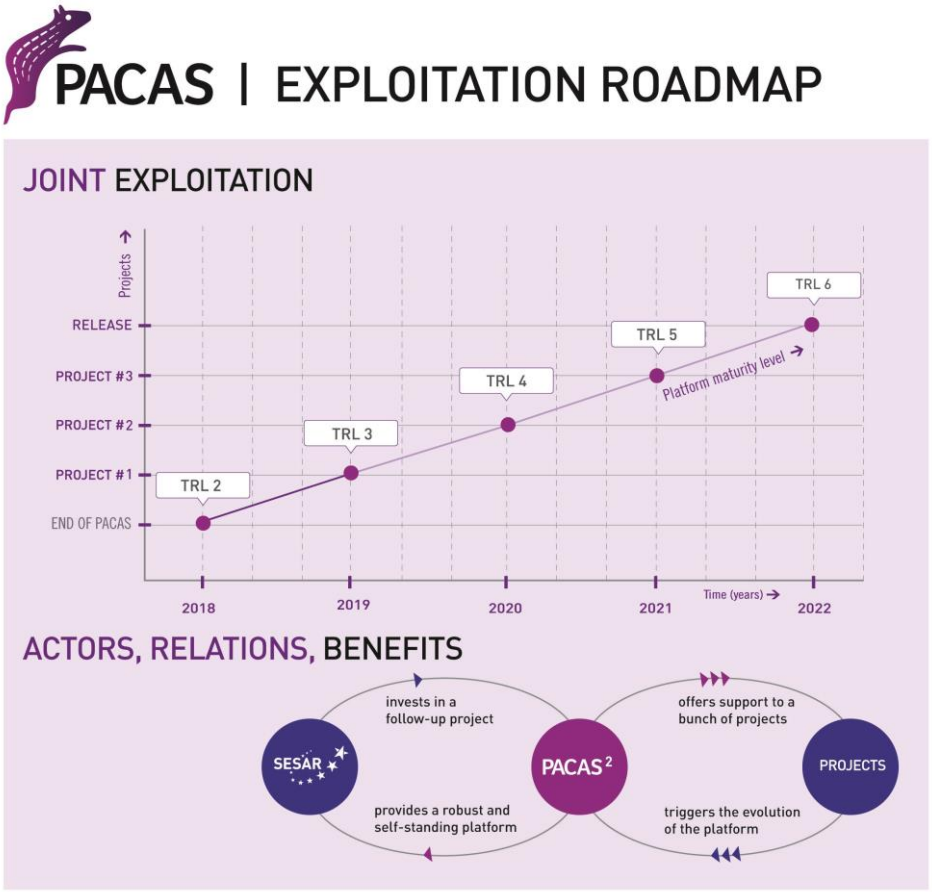

Figure 10: Joint exploitation roadmap

An initial cost benefit analysis of this joint exploitation strategy seems indicating possible positive effects of founding a new PACAS project having the aims described above. The application of the

PACAS platform to the SESAR projects (both during its development process and even more afterwards) has the potential to:

- increase quality and robustness of the solution produced, ensuring that its final design is based on a combined and cooperative analysis of its implications on safety, security, organizational aspects and environment from the different perspectives of the various stakeholders involved
- reduce time and costs of the solution design and development process, contributing to early detection and exclusion of unsuitable design options.

4.4 Synergies with other projects

As strongly recommended by SESAR, a fruitful collaboration was initiated with other EU funded research projects for sharing information, discussing results and providing a holistic approach on emerging challenges. In particular, PACAS coordinated part of its dissemination activities with STRESS, MOTO and TACO, three H2020 projects dealing with future automation in ATM and its impacts on human performances.
These projects are relevant to PACAS as they are investigating future scenarios and exploring the implementation of new technologies in the complex system that is ATM; the platform developed by PACAS may help evaluating the outcomes these projects propose.
In addition, these projects provide various novel scenarios, which PACAS can help to support decision making in analysing different options, thus allowing stakeholders to evaluate their impact on the safety, security, organisational and economic aspects (see D6.3 and D6.4).
In addition to the focus on change management, these projects relate to PACAS as the platform PACAS develops can help evaluating how the solutions proposed by MOTO, STRESS and TaCo impact on ATM with regard to safety, security, and organisational and economic aspects. In order to highlight these common aspects, the projects took any chance to cross-reference each other and produced a coordinated set of factsheets to present at SIDs 2017 (as illustrated in the following picture). Finally, together with these projects, PACAS was selected for the Common Dissemination Booster (CDB). It is a brand-new service from the European Commission available to all European, National, Regional funded Research & Innovation (R&I) projects (H2020, FP7 or other). The booster encourages projects to come together to identify a common portfolio of results and shows them how best to disseminate to end-users, with an eye on exploitation opportunities.

Figure 11: TaCo, MOTO, STRESS and PACAS presented coordinated factsheets at SIDs 2017

We have also explored potential synergies with new projects under the same topic, related to ATM Operations, Architecture, Performance and Validation, in particular Evolutionary ATM (EvoATM) and DOMINO.

Being from the same topic, the overall objectives of these projects are similar to those of PACAS, i.e., understanding the repercussions of change over the ATM system, but the proposed solutions are directed at different layers of abstraction and make use of different techniques. In particular, both EvoATM and DOMINO make use of agent-based modelling and simulations to understand the impacts of change.

Similarly to PACAS, their solutions will be based on the analysis of existing historical and ongoing scenarios to prove the correctness of their approach. However, the solutions we offer are complementary. While PACAS supports multi-view modelling and different languages for the various involved experts and decision-makers, DOMINO considers the use of a holistic model to support simulation and the analysis of change from the different stakeholders. DOMINO will provide a view of the impact of deploying solutions in different manners, e.g., harmonized vs. local/independent deployment, and information on the criticality of elements in the system and how this might be different for different stakeholders. Their main focus is on planning, and efforts need to be made to link how that affects the four perspectives covered in PACAS, namely security, safety, organizational and economic. One possible synergy, would be that of providing the front end for DOMINO to visualize and offer the opportunity of the different experts to work together on the common model while running what-if analysis as part of their simulations.

EvoATM on the other hand, will adopt sensitivity analysis strategies in order to understand the influence of ATM components parameters on the behaviours at component performances level (behaviours of other components) and at whole system performances level. It will test the framework by using known scenarios and quantitative indicators to validate its effectiveness in terms of: change impact assessment, support to design and support to strategic thinking. A potential integration with PACAS may provide the possibility to include EvoATM analyses as services in the PACAS platform. This will require efforts to establish how the results can be visualized and made useful to EvoATM users.

Although these are some general ideas after an initial interaction with the corresponding coordinators of the two projects, one concrete step is that of involving one or two PACAS partners as part of the Advisory Boards of these two projects, in order to facilitate both our understanding of the work being done but also bring in ideas from the already accomplished work in PACAS.

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Appendix A

A.1 Glossary of terms

Term	Definition	Source of the definition
….		

Table 4: Glossary

A.2 Acronyms and Terminology

Term	Definition
ATM	Air Traffic Management
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)

Table 5: Acronyms and technology