Final Project Report WP-E

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Abstract

The final report of the SPAD project provides a publishable summary of the results. In addition it lists all deliverables, dissemination activities, eligible costs, deviations, bills and lessons learned.

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This deliverable consists of SJU foreground.

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Publishable Summary

Context of SPAD project

SESAR is aiming at a significant overall productivity improvement in Air Traffic Management (ATM). A key enabler for this improvement is an increase of automation. Automation will support and in some long-term case even completely replace human operators, in order to meet the new capacity and efficiency necessities. Humans will be able in this way to manage a higher number of tasks and will shift from direct control activities towards more strategic roles (from an operator-in-the-loop to an operator-over-the-loop approach). However, automation brings a range of new challenges including those related to possible degradations. In particular, high levels of automation imply low system flexibility. A system which has been carefully planned, and thus standardized and automated, is hardly able to deal with non-standard and unplanned events such as those caused by technical failures. In addition, the components of a highly automated system are usually tightly interconnected. The consolidation programme of the ATM architecture will lead to fewer control centres through Europe. Contribution to this increased interconnection will also come from the new gate-to-gate solutions, from the implementation of the SWIM architecture with less information asymmetries, and from the tighter links among all the stakeholders needed to offer a coherent and homogeneous service and interoperability. Increased coupling may make harder to identify and isolate failures when they occur, and to detect minor malfunctions before they propagate to the whole system. Then, coupling and lack of flexibility can bring to a higher sensitivity of the ATM system to degradation problems.

Degradation propagation is the area of investigation of the SPAD project, whose aims were:

- understand, model and estimate the propagation of automation degradation in ATM;
- evaluate and estimate the consequences of degradation propagation on ATM performances;
- support an effective intervention for the containment of automation degradation.

The SPAD approach

We consider ATM as a system of systems that combine their resources and capabilities in order to achieve a common goal. Modelling of system of systems is particularly complex due to a set of reasons that include: the need to consider multiple levels and domains; the overall complexity and variety of the system elements; the level of uncertainty that remains in their behaviour and interactions. In SPAD we approached the problem by using a Federation of Models, offering different perspectives of the system under study and analysing it at different levels of granularity. Since we focus on a specific aspect of the ATM system (its ability to contain and manage automation degradation) we don't need a full abstraction of it. We selected models that can investigate specific characteristics and whose joint capabilities offer sufficient information for the questions of interest.

Models are used within the context of a Federation. Use of a Federation facilitates the integration of the analysis and of the information offered by the different models, through the adoption of compatible representations and format and the definition of a common scope for the models. The models of the Federation can work at different levels of abstractions from the single system till the top system of systems level. When operating at the single system level models consider what is required for the system to carry out its operations and to manage and tolerate possible degradations. When operating at the integration level the models consider interaction and coupling between the different systems, to understand and measure degradation propagation and the link with the overall performances.

SPAD Federation of Models

The SPAD Federation is based on three complementary models offering different views of the system under study: FRAM, HAMSTERS and ICOs. FRAM has been proposed as a method for the analysis of complex socio-technical systems, which may be able to overcome the limitations of traditional methods that focus on simple cause and effect relationships. FRAM on its own may be useful for

modelling the system at a high level of abstraction. HAMSTERS is used to provide a deeper understanding of human functions, and ICO-Petshop is used to model technical system functions at a very detailed level. This Federation of Models is accompanied with a modelling process that makes explicit which modelling technique is used in which phase and what are the information exchanges and connections between the models.

Not all the models have been used in all the applications. Indeed, while extremely useful for describing, analysing and understanding complex systems, model-based analysis is time and resources demanding. This forced to focus on the representation of information that are essential for the analysis under consideration. For example, the main case study of the project used the FRAM model as a main artefact for analysis helped with HAMSTERS for representing operators' tasks at a high-level of abstraction (not dealing with user interface elements for instance).

Case Studies

The Federation was applied in two case studies from the ATM world.The first case study deals with the Arrival Manager (AMAN), a ground based planning tool suggesting to the air traffic controller an arrival sequence of aircraft and providing support in establishing the optimal aircraft approach routes. AMAN is a decision support tool, not a replacement for the human activity, and can be classified as a system with level of automation between 2 and 3 of the Parasuraman's scale. On that system, SPAD considered three possible types of degradation of growing levels of severity. This case study has been used for the first experimental applications of the federation and supported the tuning of the models and the refinement of the overall SPAD approach.

The second case study regards a Remotely Piloted Aircraft System (RPAS), where Remotely Piloted Aircraft (RPA) are able to self-separate from each other and from the surrounding commercial traffic using automated self-separation algorithms and ADS-B based localization devices. Remote Pilots (RP) supervise the flight of the RPA and intervene only in case of malfunctions or unforeseen events. The RP can also intervene modifying the trajectory of the RPA if required by an ATCO or other authorised personnel. For this reason we adopted the acronym RPAS even if the aircraft is using its own self-separation algorithm (that is, it could be considered autonomous rather than remotely piloted). The procedure adopted for both the RPAS flying procedures and the management of the possible malfunctions are in line with the strategy proposed in the SESAR study ICONUS (Initial CON OPS for UAS in SESAR). The level of automation of the RPAS can be classified between level 7 and 10 of Parasuraman's scale and it offered the opportunity for a complete and realistic application of the consolidated version of the Federation.

The possible degradation considered for the RPAS case study were:

- interruption of the communication channel between RPA and RP (the RPA is still able to self-separate from the other aircraft, however it cannot be monitored and supervised effectively by the RP);
- interruption of the communication channel and failure of the self-separation algorithm (the ATCO is able to recognize that an emergency event is taking place and to identify the area of the problem);
- interruption of the communication channel, failure of the self-separation algorithm and failure of the localization device of the RPA (there is a failure of the ADS-B service and localization is only possible through radar).

There were some minors additional experimental applications of the Federation to test the possible contribution of additional models such as ICO-Petshop, for example the WXR case study dealing with a weather radar's user interface for large civil aircraft.

SPAD Demonstrator

The SPAD Demonstrator aims at simulating a large geographical area with a mix of traditional commercial aircraft and RPAS. The aim is to reproduce the conditions needed for the second case

study, simulating the potential impact of RPAS malfunctions over the whole ATM system. The Demonstrator has been designed and implemented following the principles of Agent Based Modelling, simulating the actions and interactions of autonomous agents (both individual and collective entities such as organizations or groups) with a view to assessing their effects on the system as a whole.

The system is composed of two fundamental components:

- The network is a graph representation of a real air-traffic network, composed of waypoints (graph vertexes) and routes among them (graph arcs);
- The agents are aircraft flying on the network. There are two classes of agents: traditional manned aircraft and remotely piloted aircraft (RPAS).

The main functionalities of the Demonstrator are:

- The identification of conflict-free routes for all the agents, commercial and RPAS, involved in the simulation, basing on their starting point and destination (planning phase);
- The movement of the agents along the routes computed in the planning phase (execution phase);
- The introduction of the RPA malfunctions described in the "Case Studies" sub-section, leading to the creation of non fly safety areas and the consequent routes re-planning by all the involved agents (re-planning phase).

The Demonstrator can generate different possible normal and abnormal operational conditions that can then be analysed applying the Federation of Models. The Demonstrator can also offer the opportunity to present and discuss the results of the project with potential stakeholders, evaluate the best way to present information about the effect of degradation and identify possible future evolutions of the SPAD concept.

Main results and Lessons learnt

The aim of SPAD is to support the understanding modeling and estimation of automation degradation and its consequences in ATM. Significant advancement has been achieved in this direction but with some limitations in the real time application. The approach adopted by SPAD is to use a Federation of Models tuned and adapted through a set of case studies. The Federation is based on a set of synergetic and complementary state of the art models for system analysis and evaluation. These models require a significant human contribution, and the interactions between the models shall be managed by a human analyst. The significant human (non automatable) effort required and the limited automated support by application tools make difficult to use the Federation for real time purposes.

To overcome this real time limitation, the Federation of Models has been used off line to explore in advance a limited number of possible future events, of the ATM system under study, and estimate their possible consequences. Realistic conditions for these events were generated using the project Simulator. The functioning of the system was then simulated and monitored in real time, and if there was evidence that one of the explored events was going to happen, the estimate about the possible consequences was used to manage the event. This strategy is very effective to monitor and manage possible degradations but is expensive in terms of application effort. The analysis becomes gradually less informative for each variation of the operational conditions of the event, and each variation requires additional human analysis.

The approach developed in SPAD is more cost effective to support the analysis of systems, for example as a support to safety assessment and safety analysis. In such a case, the Federation of Models can support the interaction between the analyst and the operational experts, and the representations and preliminary analysis of the Federation can be used to elicit the opinion of the operational experts in a structured and stimulating way. When the complexity of the system under

analysis grows, the application effort can be significant because of the different instantiations required for each possible set of events to be investigated. In such a case, the analysis shall focus on the most relevant parts of the system and choose the right combination of levels of granularity for its parts.

The use of a realistic Simulator, generating data about possible normal and abnormal operational scenarios offered the opportunity to apply the Federation of models to different possible realistic cases. In this way the Federation of models was "tested in practice" and improved on the basis of the feedback gathered from its application. This use of the Simulator was key for achieving an effective and realistic validation of the project outcome and to allow an objective evaluation of the results achieved.

1 Introduction

1.1 Purpose of the document

The purpose of this document is to:

- Summarise the technical results and conclusions of the project (Publishable Summary);
- Provide a complete overview of all deliverables;
- Provide a complete overview of all dissemination activities (past and in progress). Where appropriate, provide feedback from presentations. Describe exploitation plans.
- Provide a complete overview of the billing status, eligible costs, planned and actual effort (incl. an explanation of the discrepancies).
- Analyse the lessons learnt at project level.

1.2 Intended readership

The document is intent to be used by the SPAD Project Officer, the SESAR JU and EUROCONTROL organizations to have an overview of the SPAD project, the project results and lessons learnt. The document also contains a summary of the project deliverables, dissemination activities, eligible costs and bills and provides a picture of the project activities in the past 28 months.

1.3 Inputs from other projects

None.

1.4 Glossary of terms

Term	Definition
ACC	Area Control Centre
AMAN	Arrival MANager
ANSP	Air Navigation Service Provider
ATCO	Air Traffic COntroller
ATM	Air Traffic Management
E-ATMS	European Air Traffic Management System
FRAM	Functional Resonance Analysis Method
HAMSTERS	Human-centred Assessment and Modelling to Support Task Engineering for Resilient Systems
RPA	Remotely Piloted Aircraft

Term	Definition
RPAS	Remotely Piloted Aircraft System
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme that defines the Research and Development activities and Projects for the SJU.
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Programme	The programme that addresses all activities of the SESAR Joint Undertaking Agency.
UAS	Unmanned Aircraft System

2 Technical Project Deliverables

Number	Title	Short Description	Approval status
D1.1	Case study scenarios	This deliverable presents the two case studies investigated within the SPAD project. Each case study presents a detailed description of the operational context where the system under analysis is implemented and a representation of possible system's degradations. The first case study involves the AMAN (Arrival Manager) system while the second one deals with UAVs (Unmanned Aerial Vehicles).	Approved
D5.1	Joint event review	This document contains the paper presented at SESAR Innovation Days, 29th Nov-1st Dec 2011. The title of the paper was "System Performances under Automation Degradation (SPAD)" and illustrated the premise for the SPAD project, the main objectives of the project and the proposed research approach.	Approved
D5.2	Dissemination and external coordination	This document presents the different communication and dissemination actions carried out from May to December 2011 of the SPAD project life, i.e. the long paper presented at ATACCS 2011, the article and presentation at IEEE SMC 2011 and the paper and presentation for SID 2013.	Approved
D1.2	Degradation lifecycle analysis	The document presents an analysis of the propagation of automation degradation, and the possible consequences of the degradation on the overall ATM system and on its performances. The goal of this work is to identify patterns and general behaviours in different cases of automation degradation, and appropriate ways to characterise both the impact of degradation overall the ATM system and how degradation propagates. In particular, the focus is in understanding the effects that the automation degradation introduces in the system and to see how these effects can affect the system resilience, i.e. in the ability of the system to deal with change requests due to an emergency.	Approved
D2.1	Federation specification	This document presents a first description of SPAD framework aiming to support analysis of consequences of automation degradation. Modelling, methodological and computing requirements are described in order to support the definition of Federation of Models. A first prototype of Federation of Models dedicated to the modelling of large-scale socio-technical systems components is presented.	Approved
D2.2	Federation of models	Objective of this document is to describe SPAD federation of models, results of the activities 2.2 and 2.3 of the SPAD project. The document is structured in four parts. The first part is related to the description of the modelling context. The second one is dedicated to the presentation of the collection of models selected. The third one aims to describe SPAD federation of models. The final section is related to the illustration of the application of the Federation of models.	Approved

D5.3	Joint event review	This document contains the paper “A framework for modelling the consequences of the propagation of automation degradation: application to air traffic control systems” presented at SESAR Innovation Days (SID), 27th 29th December 2012. It is made up of two parts. First one corresponds to the paper submitted to SID and the second part contains the slides used for the presentation.	Approved
D5.4	Dissemination and external coordination	This document presents the different communication and dissemination actions carried out for SPAD project from January to December 2012. It also present some information about the feedback received from the audience following these dissemination activities when available. The activities presented in the deliverables include the paper and presentation for SID 2012, the SPAD website, the paper and presentation for ATACCS 2012, and the paper and presentation for the CHI2012 workshop “End-user Interactions with Intelligent and Autonomous Systems”.	Approved
D3.1	Revised UAS simulators	This document present the first version of the SPAD Simulator and its functionalities. The SPAD Simulator is designed and developed to reproduce the UAS scenario and support its analysis in the different degradation situations. The Simulator consists in a set of integrated components able to visualize and represent the air-traffic in a delimited geographical area. The simulated traffic is supposed to be composed of a mix of traditional commercial aircraft and RPAS, in order to study the potential impact of RPAS malfunctions over the whole ATM system providing data for the Federation of Models. Also, the Simulator GUI will be the grounding of the SPAD Demonstrator tool developed in WP4. The deliverable includes a description of the role of the Simulator within the project and how the Simulator is expected to interact with the federation of models.	Approved
D4.1	Demonstrator specification	This deliverable provides a description of the functionalities of the SPAD demonstrator. The content is the basis for the production of the demonstrator specifications. The Deliverable discusses how the features and the possible information that can be provided by the Federation of Models can be exploited to support the stakeholders in monitoring the ATM system, supervising the potential propagation of degradations and identifying actions for its containment. Screenshots of the output that could be provided by the demonstrator are offered as examples to clarify and illustrate the functionalities to be developed. These functionalities have been discussed with the support of operational experts and safety managers and a summary of their recommendations is included in the deliverable.	Approved

D3.2	Validation	This report describes the organisation, and the results of the SPAD validation activities. It starts with the identification of the elements at the basis of the SPAD approach, and of the process for its application (that is, what has been validated). Then the report describes the main characteristics that are important for the potential users of the SPAD Federation, and that have been investigated during the validation. These characteristics are: the correctness of the information provided; the applicability in terms of effort and of the qualification required; the ability to analyse systems of different size and complexity; the cost effectiveness of the approach and the usefulness of the output. The report continues describing how these characteristics have been decomposed into more easily measurable sub-characteristics and how these have been investigated. These sub-characteristics that have been investigated in the validation exercises are: the ability to predict the behaviour of the system and in particular the variability of its functions and the effect that this variability can have on the overall system performances; the degree to which the federation of models lead to consistent analysis between different users; the theoretically soundness of the Federation models; the degree to which the overall SPAD approach is reasonably easy to understand and use; the degree to which the overall SPAD approach can be applied to systems of high complexity with a reasonable increase in cost and workload; the ability to suggest effective solution for the reduction and mitigation of unwanted system behaviours. Conclusions provide the results of the investigation activities and a summary of the main indications that can be derived from the validation.	Approved
D4.2	Prototype of the Demonstrator	The deliverable presents the final version of the SPAD Demonstrator, illustrating the purpose of the demonstrator and its functionalities. The document presents also some illustrated examples of the demonstrator applied to the UAS case study. Together with the demonstrator, the deliverable presents illustrated guidelines for the Federation of Models application. In the deliverable appendix, the full application of the Federation of Models to the UAS case study is reported.	Under Approval
D5.5	Joint event review	This document contains the paper and slides presented at SESAR Innovation Days, 26th-28th of November 2013. The title of the paper is “From Modelling to Performance Prediction. Asynchronous Connection of SPAD Federation of Models to RPAS Simulator” and presents a modelling approach for analysing consequences of automation degradation in the context of large socio-technical systems.	Approved
D5.6	Dissemination and external coordination	This document presents the different communication and dissemination actions carried out for SPAD project from January to December 2013. It also present some information about the feedback received from the audience following these dissemination activities when available. The activities presented in the deliverables include the paper and presentation for SID 2013, the SPAD website, the paper and presentation for ATACCS 2013, and the paper and presentation for SAFECOMP 2013 and REA 2013.	Approved

Table 1 - List of Project Deliverables

3 Dissemination Activities

The work done during the SPAD project has regularly being submitted to various conferences and events associated to various communities. Articles presenting the work done in the SPAD project have been submitted each year to the SESAR innovation days and to the ATACCS conference. Also, the project periodically updates its two website pages to disseminate towards the general public and the HALA! Network.

3.1 Dissemination towards General public and HALA! Research Network

The SPAD Project website is accessible since November 2011 and is updated monthly. It is available at the following address: http://www.irit.fr/recherches/ICS/projects/spad/. The website is continuously updated containing detailed information about SPAD project activities and productions, including the list of research papers and deliverables. The IRIT website is also directly connected to the HALA! webpage dedicated to the SPAD project (http://www.hala-sesar.net/spad). The information reported in the first site is duplicated in the other website. However, differently from the IRIT page, from the SPAD page in the HALA! Website it is possible to download the project approved deliverables.

Figure 1: SPAD website's Homepage - IRIT

Figure 2: SPAD website's Homepage – HALA! Network

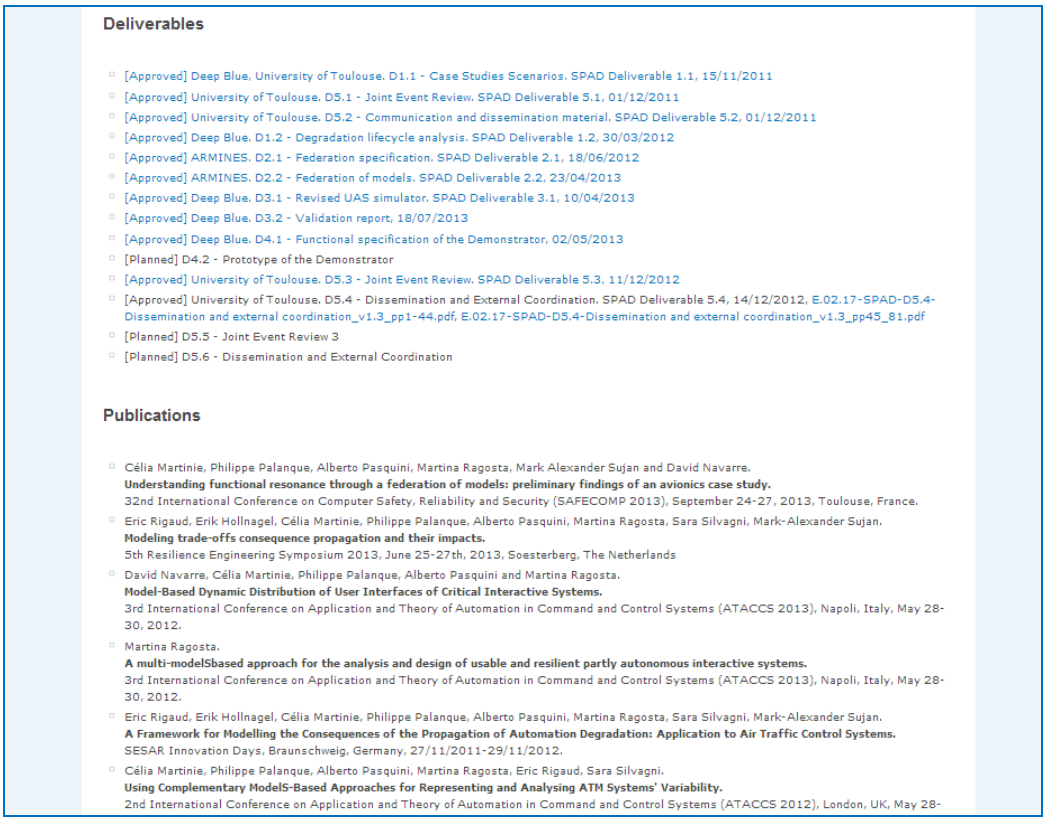


Figure 3: SPAD website on HALA! Network, list of deliverables and publications

3.2 Dissemination towards SESAR innovation days (SESAR community)

SESAR innovation days have been an opportunity to present to the SESAR community the on-going work and the achievements of the SPAD project.

3.2.1 SESAR Innovation Days, Stockholm, Sweden, November 26-28, 2013

For SID 2013, the SPAD project members submitted a paper entitled “From Modelling to Performance Prediction: Asynchronous Connection of SPAD Federation of Models to RPAS Simulator” [2]. The authors are: Célia Martinie, Philippe Palanque, Alberto Pasquini, Martina Ragosta, Sara Silvagni, Mark-Alexander Sujan, Eric Rigaud, Erik Hollnagel. The focus of the contribution is on how the SPAD federation of models can be connected to system behavior either it is being represented by a specific model or by a simulator.

The presentation of the paper is scheduled for November 26th, 2013.

3.2.2 SESAR Innovation Days, Braunschweig, Germany, November 27-29, 2012

For SID 2012, the SPAD project members submitted a paper entitled: “A Framework for Modelling the Consequences of the Propagation of Automation Degradation: Application to Air Traffic Control Systems” [3]. The authors are: Eric Rigaud, Erik Hollnagel, Célia Martinie, Philippe Palanque, Alberto Pasquini, Martina Ragosta, Sara Silvagni, Mark-Alexander Sujan. The aim of this publication is to define an overall design framework of automation degradation propagation in complex networks, and an associated method supporting the framework in order to study automation and more precisely automation degradation. During the conference, after the presentation, there was a general interest in understanding the real effectiveness of the federation of models.

3.2.3 SESAR Innovation Days, Toulouse, ENAC, 29/11/2011-01/12/2011

For SID 2011, the SPAD project members submitted a paper entitled: “System Performances under Automation Degradation (SPAD)” [4]. The authors are: Erik Hollnagel, Celia Martinie, Philippe Palanque, Alberto Pasquini, Martina Ragosta, Eric Rigaud, Sara Silvagni. This contribution describes the context and objectives of the SPAD project. It also presents the early findings by the SPAD project after 6 months of work and the investigations that were planned to be carried out for the remaining time of the project. During the conference, after the presentation, feedback was very positive. The idea of the federation of models impressed the audience. Most of the questions were on the model chosen for populating the federation and on the possible use of UML in the federation.

3.3 Dissemination oriented towards ATACCS (Scientific community linked to SESAR)

ATACCS conferences have been an opportunity to present to researchers and practitioners interested in topics related to automation the problematic related to the SPAD project and the SPAD approach.

3.3.1 3rd International Conference on Application and Theory of Automation in Command and Control Systems (ATACCS 2013), May 29-31, 2013, Napoli, Italy

For ATACCS 2013, a paper entitled “Model-Based Dynamic Distribution of User Interfaces of Critical Interactive Systems” [5] has been submitted. The authors are: David Navarre, Célia Martinie, Philippe Palanque, Alberto Pasquini and Martina Ragosta. The contribution proposes an approach for automating User Interface distribution at runtime. The approach is based on part of the SPAD federation of models. During the conference, after the presentation, the attendees were interested by the perspective of automating the distribution of user interfaces at runtime. They raised the relevant point of the implications of such automation on operations.

3.3.2 2nd International Conference on Application and Theory of Automation in Command and Control Systems (ATACCS 2012), May 28-31, 2012, London, UK

For ATACCS 2012, a paper entitled “Using Complementary ModelS-Based Approaches for Representing and Analysing ATM Systems' Variability” [1] has been submitted. The authors are Célia Martinie, Philippe Palanque, Alberto Pasquini, Martina Ragosta, Eric Rigaud, Sara Silvagni. This contribution proposes a systematic approach able to represent and to reason about the variability of such socio-technical systems. It is based on the synergistic use of three models able to represent the variability from different points of view. This federation of models focusses the analysis on the relevant aspects of the systems of systems at different levels of granularity. During the conference, after the presentation, several researchers from the SESAR community but also from other communities (such as researchers involved in the NextGen program) were interested to have more details about our approach. For most of the scientists, FRAM is a well-known method often used for incident and accident analysis and they found it very interesting to be able to integrate it with concrete design and development notations and tools in order to evaluate system performances in early development phases. They also noted that performance variability assessment for Large Scale Socio Technical Systems was very complex and that the SPAD methodology was a way to start investigating this problem.

3.3.3 Conference on Application and Theory of Automation in Command and Control Systems (ATACCS 2011), May 26-27, 2011, Barcelona, Spain

For ATACCS 2011, a paper entitled “Formal Tasks and Systems Models as a Tool for Specifying and Assessing Automation Designs” [6] has been submitted. The authors are: Celia Martinie, Philippe Palanque, Eric Barboni, Marco Antonio Winckler, Martina Ragosta, Alberto Pasquini, Paola Lanzi. This contribution proposes a contribution for reasoning about automation designs using a model-based approach exploiting both task models and system models. Tasks models are meant to describe the tasks and actions to be performed by the operator while system models represent the entire behaviour of the interactive system. During the conference, after the presentation, the approach of co executing two types of models interested the audience. Some of the attendees asked for more details about notations for representing human activities.

Another paper entitled “Exploiting gaming research and practice for engineering interactive critical systems” [7] has been submitted. The authors are: Philippe Palanque, Regina Bernhaupt, Florent Montesano, Célia Martinie. This contribution reports on work that has been carried out in the area of games to support the engineering of autonomous systems. It provides a set of design guidelines, processes, and evaluation techniques applicable to the domain of safety-critical interactive command and control systems. After the presentation, the attendees agreed that gaming research is an interesting area to exploit in order to investigate on automation problems.

3.4 Dissemination oriented towards external audience (other scientific communities)

The SPAD project and the work performed around its main associated research themes has been presented in several conferences related to different research and application domains.

3.4.1 Conference on Computer Safety, Reliability and Security (SAFECOMP 2013), September 24-27, 2013, Toulouse, France

SAFECOMP conference is a recognized conference in the safety domain and dependable computing domain for practitioners as well as for academic scientists. Then, the SPAD consortium decided to submit an article at the end of the project, when the federation of models was mature enough. The submitted article is entitled “Understanding functional resonance through a federation of models: preliminary findings of an avionics case study” [8]. The authors are Célia Martinie, Philippe Palanque, Alberto Pasquini, Martina Ragosta, Mark Alexander Sujan and David Navarre. This contribution aims at discussing the relevance about using FRAM utility for modeling interactions at greater levels of detail. A federation of models has been applied to investigate situations that may give rise to functional resonance in an avionics case study. FRAM was used to model higher-level dependencies, HAMSTERS was used to provide a deeper understanding of human functions, and ICO-Petshop was used to model technical system functions. During the conference, after the presentation, several researchers from the dependable computing domain came to discuss with us about our approach. They were interested in the multi-models description of complex systems, especially in the approach of connecting at runtime system models to safety analysis models.

3.4.2 5th Resilience Engineering Symposium 2013, June 25-27th, 2013, Soesterberg, The Netherlands

Resilience is one of the key topics of the SPAD project and then, a poster entitled “Modeling trade-offs consequence propagation and their impacts” [9] has been presented at the 2013 Resilience Engineering Symposium. The authors are Eric Rigaud, Erik Hollnagel, Célia Martinie, Philippe Palanque, Alberto Pasquini, Martina Ragosta, Sara Silvagni, Mark-Alexander Sujan. This contribution describes a model of automation variability propagation in a complex network. A modeling context constituted of network-based model and socio – technical system fundamental trade-offs is used to structure a four level propagation model. Poster presented at Resilience Engineering V conference raised several discussions. First of all, with regards to the complexity of the propagation model, attendees asked whether there were guidelines defined for helping analyst to optimize modeling time efforts in focusing on relevant dimensions for the intended use of the model. This discussion raised the necessity to define trade-off rules between model quality and time efforts to produce it, considering the context and the objective of the modeling process. Then, attendees wondered how to manage data collection with regards to the various dimension of the model. Data collection process concerns technical information, human information, organizational and inter-organizational information. Some attendees evocated the problem of collecting information from and interacting with people of different cultures. Lastly, some attendees discuss the fact that the method seems to be fractal and that it could maybe be possible to apply the same method to deal with heterogeneous data and phenomenon. The interrogation of FRAM being a relevant method to model technical, human, organizational and inter-organizational functions and interdependencies has been raised.

3.4.3 European Conference on Cognitive Ergonomics (ECCE 2012) August 29th-31st 2012, Edinburgh, Scotland

Philippe Palanque has been invited as a keynote speaker for the ECCE Task Models as a Central Artefact for Designing, Building and Operating Safe, Usable and Reliable Interactive and (partly-) Autonomous Applications [10]. During this invited presentation, he presented the SPAD project and discussed the need for a broader view in order to design Interactive Systems, arguing that interaction

and interfaces are only the very small visible side of the iceberg. It emphasised the tremendous support offered by tasks models especially when automation and function allocation have to be designed especially in the area of command and control systems where higher levels of automation remain a recurring target. Most of the attendees were coming from the cognitive sciences area. They provided encouraging feedback about the notation and tool used in the SPAD project to describe and analyse human activities.

3.4.4 Workshop on Human Factors for Intelligent Vehicles (HFIV 2012), June 2012, Madrid, Spain

Philippe Palanque has been invited as a keynote speaker for the “Automation in command and control systems: what should be remembered and what should be forgotten when designing Safe, Usable, Reliable and Enjoyable intelligent vehicles” [11]. During this invited presentation, he presented the SPAD project and he highlighted knowledge that has been gained in the area of air traffic management and aviation around the notion of (partly-) autonomous systems and automation. This presentation drew parallels with current trends in ground vehicle systems design highlighting commonalities and discrepancies. One of the main discrepancies being around the user experience factor which is very prominent an exhibited for car drivers while being of very low importance (and most of the time even hindered) in civil aviation. It also highlighted the issue of "intelligence" degradation and how such degradation could have on usability, safety and dependability of in-car embedded systems. After the presentation, the issues around AMAN user interface and user interaction design, specification, implementation and evaluation were discussed in a vivid way during the meeting and several nice contributions were proposed. In a nutshell, the workshop attendees identified AMAN as an intelligent assistant and they pointed out to previous contribution in that field that would be relevant. They also pointed out ones which would not be applicable to the safety critical nature of ATC work. The aspect of degradation was perceived very innovative and not covered in previous work.

3.4.5 Workshop on End-user Interactions with Intelligent and Autonomous Systems. ACM SIGCHI Conference on Human Factors in Computing Systems (CHI 2012), May 5-10th, Austin, Texas, United States

ACM SIGCHI conference in Computer Human Interaction (CHI) is a recognized conference in the human computer interaction domain for practitioners as well as for academic scientists In order to gather some feedback from this community but also to advertise the automation research topic, the paper entitled “Some Issues with Interaction Design and Implementation in the Context of Autonomous Interactive Critical Systems” [12] has been submitted to a workshop of the conference about End User Interactions with Intelligent and Autonomous Systems. The authors are Célia Martinie, Philippe Palanque, Martina Ragosta. This contribution aims at raising some issues related to the design and implementation of safety-critical user interfaces featuring intelligent and (partly) autonomous behaviors. Designing interfaces that will be used to operate intelligent systems and (partly) autonomous systems is a very complex activity altering in depth the development process of these systems. During the workshop, after the presentations, the attendees have been working on the particular topic of automation in command and control rooms. They became aware of the difficulty of designing human automation interaction in critical contexts.

3.4.6 IEEE International Conference on Systems, Man and Cybernetics (SMC 2011), October 9-12th, 2011, Anchorage, Alaska, United States

An article entitled “Task Model Based Assessment of Automation Levels: Application to Space Ground Segments” [13] has been submitted to the conference IEEE SMC. The authors are Celia Martinie, Philippe Palanque, Eric Barboni, Martina Ragosta. This contribution proposes a contribution

for reasoning about automation designs using a model-based approach exploiting refined task models. These models describe operations with enough details in order to reason about automation and to rationalize automation designs. During the conference, after the presentation, positive feedback has been received about the accuracy of precise task modeling notation for analyzing automation in command and control system.

3.5 Dissemination oriented towards external audience (other than scientific communities)

Beyond the dissemination activities presented in previous sections, the work that has been carried out in SPAD has raised attention from other bodies. This has ended up by a set of dissemination activities (cross presentations, preparation of join work programmes, …) that are detailed in the sections below.

3.5.1 Dissemination towards NASA

Following the presentation at the IEEE SMC conference (see section 3.4.6) we have started a cooperation around the notion of automation (and automation degradation) the Human System Integration group at NASA Ames (California). This collaboration took place through a set of visits from Mike Feary to UNITO and two long research stays from UNITO members (Célia Martinie and Philippe Palanque in July-August 2013). In parallel, the Robust Software Engineering (RSE) group at NASA Ames has also demonstrated interest in the research carried out around some of the models of the federation of models developed in SPAD namely the task models description in HAMSTERS and the System Model description using ICO and the tool PetShop. A research cooperation framework is under construction that will allow UNITO and the two NASA Ames research group to carry on and extend some of the research contributions from SPAD project. As an example Philippe Palanque from UNITO is invited speaker at the AAAI Spring Symposia on Formal Verification and Modeling in Human-Machine Systems (http://www.aaai.org/Symposia/Spring/sss14symposia.php#ss03) organized by RSE group at NASA.

3.5.2 Dissemination towards CNES

UNITO has been carrying out research for more than 10 years with CNES (Centre National d'Etude Spatial) in Toulouse. In that domain (as in ATM) there is a trend of evolutions towards higher levels of automation and of course the issues of automation degradation have been perceived has of primary importance for the critical systems they are designing and managing. Following the research contribution of SPAD project a seminar on automation has been organised by CNES on September 9 2013. Mike Feary from HIS at NASA Ames, Alberto Pasquini DBlue and Philippe Palanque (UNITO) have been invited to report on issues and research direction in automation. (unfortunately the website address is private but screenshots are available from the final review meeting slides). There is good hope that SPAD team will be involved in future research programmes at CNES dealing with automation and automation degradation.

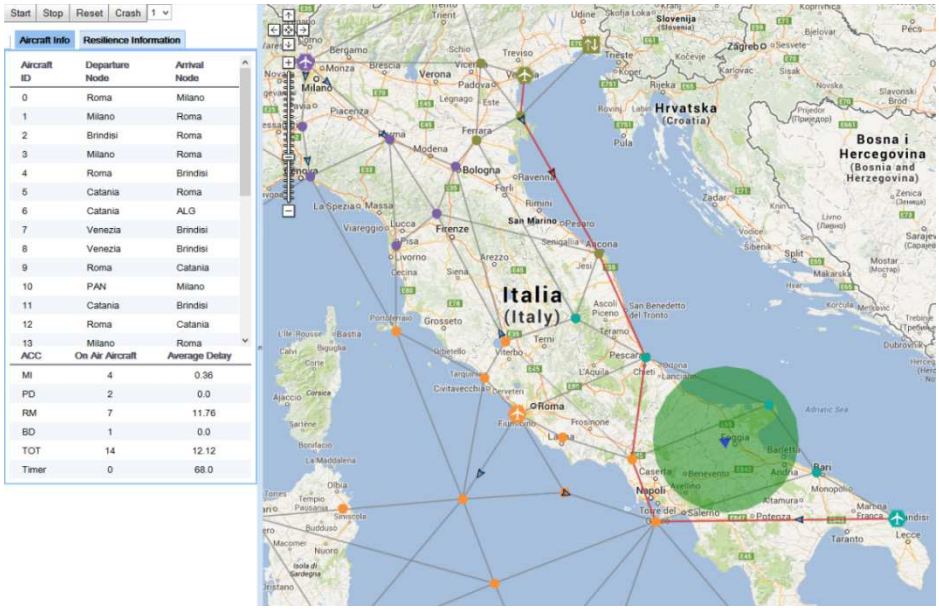
3.6 Demonstrations

Together with the Federation of Models, the project developed a Demonstrator to evaluate with the stakeholders, such as air traffic controller and safety managers, the main results and the approaches proposed in the project.

The SPAD Demonstrator simulates the traffic in the Italian airspace considering both traditional commercial aircraft and RPAS (Remotely Piloted Aircraft System) crossing non-segregated areas. The Demonstrator can simulate the effects of different possible RPAS failures and show their impact

on the commercial traffic and ATM system. Traffic data generated by the Demonstrator and information about the simulated RPAS failures are then analysed by the SPAD Federation of Models in order to understand the ability of the ATM system to tolerate and manage the consequences of the failures.

The SPAD Demonstrator can show the output of the Federation analysis evidencing the possible negative impact on the functions of the different ACCs (Air Traffic Control Centres) in the simulated airspace. The output of the Federation of Models is expressed in term of variability of the functions, i.e. the way in which individual and collective performances are adjusted to match system current demands and resources.



The enclosed figure illustrates the Demonstrator interface. Here, the Demonstrator simulates a RPAS failure caused by loss of the communication link with the remote pilot, and its impact on the ATM system. A no flight safety area is created around the RPAS (represented by the circle around the RPAS), and all the aircraft close to the RPAS are re-routed to avoid this area. The left part of the screen shows relevant information, for example the list of aircraft in the airspace and the delays caused in each ACC. Also, the Demonstrator can display the status, trend and criticality level of the different ACC functions.

During the exhibit at SESAR Innovation Days we plan to show different real-time examples of consequences of RPAS malfunctions on the SPAD Demonstrator.

3.7 Exploitation plans

The results and lessons learnt from the SPAD project will benefit the Deep Blue Company and the research community (especially in the fields of automation engineering, dependable computing and large scale socio-technical systems).

3.7.1 Expected benefits for Deep Blue

Deep Blue can rely on the experience in the SPAD project and the knowledge developed during FRAM and HAMSTERS application and their combination in a federation to:

- Improve its consulting activities in the ATM and other transport domains, proposing the Federation of Models for off-line safety analysis activities and accident investigation; in particular, this off-line analysis can be applied to the safety consulting activities performed with the Italian Air National Service Provider (ENAV).

- Improve its research activities on real-time safety monitoring, addressing the selection and monitoring of specific safety indicators, possibly related to the SESAR work on key performance indicators.

The results of the SPAD project can be exploited in the SESAR projects in which Deep Blue is involved, such as WP16 projects, and in the activities connected to our role of SESAR JU Associated for the Validation activities.

Finally, the SPAD experience can be reported and transferred to all the other international research projects related to the safety analysis in which Deep Blue is involved, such as ASCOS, ACROSS and EXCROSS.

3.7.2 Expected benefits for the University of Toulouse

For UNITO, SPAD project proposed a unique opportunity to deal with automation aspects in the area of ATM. After several years focussing on civil aircraft cockpits and satellite ground segments this project (through the expertise of Deep Blue partner) provided detailed information for application of previous research contribution to the domain of ATM. The two case studies that have been deeply studied provided different context for applying previous contribution and developing new ones. Working with ARMINES partner allowed UNITO to gain experience in the resilience method FRAM and to study its integration within development processes for interactive systems.

SPAD project has also raised some important research questions related to

- Automation levels and their translation in terms of allocation of activity between the interactive system and their operators,
- The overall performance evaluation of the couple (operator, interactive system) when automation is introduced or when higher automation levels are targeted,
- The importance of faults, errors and failures in the automation and their impact of the overall performance of the couple (operator, interactive system),
- The importance of failures propagation either happening at the operator level or at the system level,
- The importance and impact on the analysis activities of studying a large scale socio-technical system in its entirety.

These research questions have been addressed in SPAD but more work need to be done in order for the solutions proposed, to reach the maturity level required for technology transfer to industry or standards. UNITO will work on these aspects in future projects building on the knowledge and experience gathered in SPAD.

3.7.3 Expected benefits for ARMINES

The following activities conducted by ARMINES will benefit of experience, knowledge and results of SPAD project:

- FRAM modelling framework engineering. FRAM application and combination with HAMSTERS experience raise areas of improvement of FRAM method and modelling framework.

- Control of escalation in sociotechnical systems. Propagation models defined within SPAD project will be refined in order to base conceptual and applied researches aiming to model escalation in sociotechnical systems and to define control barriers.

- Technology assessment framework engineering. SPAD Federation of models will be used to define an assessment module to be added to the toolbox of assessment of change currently in development.

SPAD experience can be reported and transferred to ARMINES actual and future projects related to technology and organisational assessment in a perspective of safety management.

3.7.4 Expected benefits for the research community

SPAD project demonstrated the importance of model-based approaches for addressing large scale socio-technical systems. It demonstrated the feasibility of interconnecting models of different types coming from different research fields, but also the importance of having a federation of models for analysis of complex systems in operation. In this way, SPAD approach is conformant with the UML standard approach for computing system design where multiple notations (9) are used. As for SPAD these multiple notations are aimed at gathering various characteristics of the computing system. However, UML (or its extension SysML are not addressing human-computer interaction aspects (operators and user interfaces) which is a core element of large socio-technical systems. With that respect, SPAD federation of models presents a unique contribution in that research area that hopefully will be the trigger for further research. On the other side, the use of the federation of models on SPAD case studies as confirmed the fact that model-based approaches require adequate tool support in order to take full advantage of their benefits. This has been known for years in computing science. An example of that is the notation Statecharts that was developed together with a tool called Statemate making it adopted immediately on a large worldwide scale right after its inception. This is also true with UML which got only used when adequate tool support (such as Rational Rose) has been available. In summary, SPAD project has developed concepts, processes and methods that have been validated on two different case studies. We expect such concepts to be taken up by the scientific community to develop additional elements (such as performance evaluation techniques over the models), to develop additional tools (dedicated to the notations and to their integration) and to apply them in other contexts and domains.

4 Total Eligible Costs

Date	Deliverables on Bill	Contribution for Effort	Contribution for Other Costs (specify)	Status
15/12/2011	D0.0, D0.1, D0.2, D1.1	78.485,00	2.840,84	Paid
30/08/2012	D5.1, D5.2, D0.3, D1.2, D2.1, D0.4	75.786,82	15.970,31	Paid
23/01/2013	D0.5, D0.6, D2.2	104.583,44	5.390,92	Paid
24/09/2013	D5.3, D5.4, D0.7, D3.1, D4.1, D0.8, D3.2	115.840,08	1.411,88	Paid
17/12/2013	D0.9, D0.10, D4.2, D5.5, D5.6	165.982,82	2.771,38	To be paid
GRAND TOTAL		540.678,36	28.385,32	Confirmed

Table 2 Overview of Billing

Company	Planned man-days	Actual man-days	Total Cost	Total Contribution	Reason for Deviation
Deep Blue	929	939	Tot € 402.713,97 For effort € 382.746,67	Tot € 302.035,49 For effort € 287.060,00	There is no relevant deviation
Armines	157	185	Tot costs € 180.717,57 Costs for effort € 166.312,92	Tot contrib. € 135.538,19 Contrib. for effort € 124.734,69	No relevant deviation
UniTo	224,5	302	Tot costs € 131.490,00 Costs for effort € 128.895,45	Tot contrib. € 131.490,00 Contrib. for effort € 128.895,45	No relevant deviation
GRAND TOTAL	1310,5	1426	Tot costs € 714.921,54 Costs for effort € 677.955,04	Tot contrib. € 569.063,68 Contrib. for effort € 540.690,00	

Table 3 Overview of Effort and Costs per project participant

5 Project Lessons Learnt

What worked well?
The project team had a realistic attitude about the results and their real usefulness that helped in making them more concrete and usable. The project had also a significant effort dedicated to Validation that contributed to this correct evaluation of results, of applicability and of the possible ways to improve those results.
The project officer (PO) was very supportive, he tried to understand and help in all the circumstances and this helped to find a good balance between high level objectives and concrete outcomes. We believe this was due to both personal attitude as well as time allocated to follow the project (this is not always the case in European projects where PO have to follow too many projects to be really present)
The knowledge of the SESAR research domain was an advantage in managing and disseminating the project. This knowledge helped for several aspects including for example: to understand what the different stakeholders wanted from the project; the constraints and requests originating from the institutional aims of SESAR and EUROCONTROL; the language to use.
The use of a simulator, generating data about possible normal and abnormal operational scenarios, offered the opportunity to apply the federation of models to different possible realistic cases. In this way the federation of models was "tested in practice" and improved on the basis of the feedback gathered from these applications.
All the project partners were very familiar with the scientific issues investigated in the project and this helped to gain a shared opinion about what could have been realistically achieved.
What should be improved?
The administrative constraints of long term research projects should be as limited as possible. The work programme and solutions of WPE projects are affected by a certain amount of uncertainty due to the nature of the long term research. If the project shows that a research direction is not as promising as expected, the project should have the possibility to consider and go for alternatives. Within the same budget ceiling the Consortium should have the possibility to use the funds with more flexibility deviating from the planned allocation when needed. This is possible in the SESAR WPE projects, however at the cost of significant bureaucratic and time consuming paper work. One way to ensure more flexibility would be to allow movement of funds between deliverables, partners and cost categories within a predefined threshold.
The SESAR primary projects of the operational Workpackages (that is, WP4 to WP15) are one of the main stakeholders of the SESAR WPE projects. The communication and flow of information between the WPE and primary projects should be facilitated as much as possible. A first step would be to provide WPE projects with information about the aims and deliverables of the primary projects, for example providing access to the SESAR extranet. Another action would be to facilitate the dissemination, towards the primary projects, of information about WPE results, possible actions in this direction are: organising dedicated events, promoting the participation to SID, requiring oriented dissemination deliverables to the WPE projects.

The project coordinator is the main responsible of the work produced, however he has limited instruments to influence the quality of the work done by the partners. He has to rely on their good will and collaborative attitude. More drastic actions are possible but at very high costs in terms of administrative burdens, project image and partner reputations. This is not a specific problem of SESAR, it is typical of any co-funded research projects, for example FP7 and now HORIZON 2020 projects. Perhaps the possibility to move a certain percentage of the project budget from one partner to another could help. It would allow to shift parts of the work and compensate for significant revision work on deliverables or when non planned integration to activities of other partners are needed.
WP E project are funded at a rate of 75% of the full costs with the assumption that revenues from the research results can cover the rest of the participant costs. However, WP E projects have long term research aims and the results are mainly in terms of knowledge (hard to exploit). The new HORIZON 2020 programme is adopting a different scheme: projects are funded 100% while reimbursement for overheads is reduced, and perhaps SESAR could adopt in the future the same strategy. This seems more in line with reality and would facilitate a lot the cost statement preparation and reimbursement process.
Marginal problem was the need to produce dissemination deliverables (e.g. papers for SID) shortly after the project start when little more than the project proposal was available.

Table 4 - Project Lessons Learnt

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