Validation Management in an ATM Research Project

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Abstract: The paper describes the validation process used in the Mediterranean Free Flight (MFF). MFF was a large, six years ATM research project, sponsored by the European Commission, that studied Operational Concepts and procedures for more efficient use of airspace through the delegation of tasks related to separation assurance. The validation approaches proposed in recent validation research initiatives, and in particular in MAEVA, have been modified, integrated and applied in MFF. The paper illustrates how the project Validation Objectives were identified and investigated, to judge the adequateness of the MFF Operational Concepts, and their relation with the overall ATM objectives. Then, it describes in detail the Validation Process adopted, presenting examples of the practical methods used in the different phases, and describing the use of the Validation Data Repository, an information management resource developed by Eurocontrol, to support the collection, comparison and integration of Validation results. The paper concludes reporting the main feedback from the application of the Validation Process, and the use of the Validation Data Repository, and discusses the related advantages and disadvantages.

I - Introduction

The expansion of air transport brings with it problems of congestion and delay, and exerts growing pressure on the existing Air Traffic Management (ATM) concepts and procedures [13]. The Research and Development (R&D) community is continuously investigating new Operational Concepts that can improve the ATM services [16]. These improvements include aspects such as increased throughput or capacity; reduction of environmental impact; increase in safety; reduction of the air traffic service costs [22]. However, the R&D community shall not only develop innovative ATM concepts, but also provide adequate evidence that these concepts are able to deliver the planned improvements [4]. This evidence shall demonstrate that new procedures can work efficiently in a real life environment while addressing the problems for which they were developed. This evidence is essential to support the decision making process regarding the adoption, or the further improvements and refinements, or the rejection of the concepts under study. Too often decision makers are not sufficiently convinced by the information provided by R&D to be persuaded in any particular direction [3].

The process needed to collect and provide this evidence is called Validation. Validation as a term has wide usage. Generally it describes a process of checking that requirements have been satisfied . For example, in information technology, it is used to describe an extremely rigorous and formal process of checking that a system satisfies the requirements for which it has been developed [17], [20]. In the ATM context, and especially in ATM R&D, requirements are usually not sufficiently mature to be used as the basis for validating ideas that are still in an early stage of development. Therefore, validation in the ATM context is currently intended as the process to evaluate the adequateness of a new system or Operational Concept,

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"by demonstrating, with a desired level of confidence, its ability to operate in a real-life-environment against a pre-defined level of functionality, operability and performance" [14].

Several research initiatives addressed the validation needs of the ATM domain. The first concerted attempt to develop a more systematic validation methodology was probably a series of projects conducted under the APAS and 4th Framework research programmes of the European Community. The project VAPORETO (VAlidation Process for Overall REquirements in air Traffic Operation) provided an initial step towards validation in ATM, describing a generic framework for the validation of concepts, systems and procedures [18]. The project ASIVAL (ATM System Identification for Validation) tackled the problem of how to divide the overall validation into manageable pieces [19]. The results of VAPORETO and ASIVAL served as input for GENOVA (Generic overall validation for ATM systems) that defined a generic approach to Validation in ATM with the description of the validation activities, their inputs and outputs [9].

These projects were followed by MAEVA (Master ATM European Validation Plan), sponsored by the European Commission under its fifth Framework Programme [21]. MAEVA established an initial uniform framework within Europe for the validation of ATM concepts, defining and disseminating a state of the art approach for Validation [14]. The approach proposed became a key reference for several research projects in ATM. In recent years MAEVA has been substantially revised and is now incorporated in the more comprehensive European Operational Concept Validation Methodology (E-OCVM) [6] proposed by Eurocontrol.

The introduction of a common approach for Validation, and the definition within MAEVA of a Validation Master Plan (VMP), represented also an effort to understand the specific contribution of each single research project in the overall EU ATM research framework [14]. This is essential to ensure co-ordination between the different European research projects, ensuring complementary research efforts and avoiding duplications.

The purpose of this paper is to describe how the validation approaches proposed in the research initiatives described above have been modified, integrated and applied in the MFF (Mediterranean Free Flight) project. The MFF project was a large collaborative research project investigating innovative ATM concepts [5]. Section II of this paper introduces briefly the MFF project and the innovative concepts investigated. Section III presents the Validation Objectives of the project, formulated as high level questions, to judge the adequateness of the MFF concepts, and their relation with the overall ATM objectives. Section IV describes how the current validation approaches have been applied within MFF, and presents examples of the practical methods used in the different phases of the Validation Process. Section V summarises the use of the Validation Data Repository (VDR) in MFF, which is an information management resource developed by Eurocontrol, in liaison with MAEVA, to support the collection, comparison and integration of Validation results [10]. Section VI analyses the main feedback deriving from the use of the Validation Process and discusses the related advantages and disadvantages. Feedback and results presented in this paper refer only to the process adopted and to methodological aspects. Readers interested in the results of the MFF project, and in the validation of the related concepts can refer to [7] or access the VDR [10] where all the validation results are stored.

II - Presentation of the MFF Project

The MFF project was a large, six years project, sponsored by the European Commission under the TenT Programme. MFF was co-ordinated by ENAV (Ente Nazionale per l'Assistanza al Volo) and involved several Air Traffic Service providers, mainly from the Mediterranean area, and Eurocontrol [5]. The project objectives of MFF was to define, test and validate Operational Concepts and procedures for more efficient use of airspace through the delegation of tasks related to separation assurance. It focused on the application of those procedures in the particular geographical context of the Mediterranean area, an area located between the core European air traffic area and the States of North Africa and Middle East where a significant growth in demand is expected, especially in the long term. The MFF project has investigated four relatively new ATM concepts: Free Routing, ASAS (Airborne Separation ASsurance) Spacing & Separation, and Free Flight [5].

The concepts investigated

In Free Routing airspace users are allowed to choose their flight path without reference to a fixed route network. In Managed Airspace air traffic control continues to be responsible for the safe separation between aircraft.

ASAS concepts include applications with different degrees of delegation to aircrew of tasks related to separation assurance [1]. The basic idea behind ASAS is to enhance the co-operation between aircrew and controllers and to achieve a better allocation of tasks, relieving the controller of those tasks that could be performed by the aircrew with the same or higher level of safety [12]. In ASAS Spacing flight crews are required to achieve and maintain a given spacing with designated aircraft. The pilot takes responsibility to identify the target aircraft and establish separation based on instructions from the ground, by using dedicated on-board equipments, as the Cockpit Display of Traffic Information (CDTI) shown at the centre of the cockpit simulator of fig. 1. Responsibility for separation remains with the Controller. In ASAS Separation a flight crew of an ADS-B and CDTI equipped aircraft is cleared to ensure safe separation from an aircraft designated by the controller, in compliance with ‘airborne separation minima’.

In Free Flight aircraft are totally responsible for maintaining safe separation to other aircraft, using on-board systems and thus can choose and change their trajectories subject only to the surrounding traffic [11]. In this case controller tasks are limited to alerting services and assistance in case of emergencies.

Figure 1 - On board equipments supporting ASAS (at the center of the cockpit simulator)

The new Operational Concepts and related procedures have been defined in the early phases of the project [7] and their adequateness has been evaluated through a set of Validation Exercises that have been identified, co-ordinated and integrated as described in this paper.

III - The MFF Validation Objectives

The aim of Validation in MFF was to demonstrate the ability of new ATM Operational Concepts to operate, against a pre-defined level of functionality, operability and performance. The Validation Objectives represent a description of what is expected from the Validation Process, namely the type of information that should be provided at the end of the process. MAEVA suggests that Validation Objectives are defined with all the stakeholders in the ATM service, whose support, co-operation and advice is essential in ensuring that a proposed concept can be brought into service. For example the air traffic controllers will be interested to know if the new operational procedures will increase their workload during operation; or a manager of an ATC centre will be interested in financial aspects, safety and environmental issues are of ‘common’ interest. According to MAEVA the identification of the Validation Objectives shall be done at the beginning of the Validation Process, and guide the rest of the process, with the identification and planning of the Validation Exercises (e.g. Real Time Simulations, Flight Trials) and with the integration of the results they provide.

However, this may be difficult within a specific research project such as MFF, where the project team is operating within well defined constraints. The project is approved and funded to provide specific results that are made explicit in the Project Objectives, and these include both development and validation aspects. In some cases, like MFF, even most of the Validation Exercises such as Real Time Simulations and Flight Trials were already identified and planned, and were included in the list of the technical activities of the project when the sponsoring authority decided to fund it. This was one of the major constraints that prevented the straight application of the validation approaches proposed in the literature.

Establishing the Validation Objectives

The MFF validation team decided to derive the Validation Objectives directly from the Project Objectives, on the basis of the assumption that the analysis of the information needs collected from the different stakeholders had been done during the project definition. In particular, the MFF Project Objectives considered and reflected both the expectations of the stakeholders with regard to the specific concept under investigation and the generic expectations applicable to all ATM research projects and deriving from the ATM 2000+ strategy [8]. MFF studied new concepts for more efficient use of airspace, through the delegation of some tasks related to separation assurance, then the expectations from this specific concepts were addressed through Validation Objectives dealing with aspects such as capacity, workload, technical feasibility. Generic expectations deriving from the ATM 2000+ were addressed through Validation Objectives related to aspects such as safety, economic appraisal and environmental impact. Validation Objectives covered all these aspects and were derived directly from a detailed analysis of the Project Objectives as expressed in the relevant project documentation [15]. The MFF validation team identified eight Validation Objectives listed in Table 1. These Objectives addressed all the research subjects of MFF, that is: new concepts, new procedures, and the related supporting architecture.

Table 1 - List of the MFF Validation Objectives

1	To evaluate if controllers and pilots are able to **operate effectively** using the new procedures and tools (considering workload, situational awareness, acceptance, training, and HMI).
2	To demonstrate that each MFF concept is at least as **safe** as, or safer than, existing ones (including degraded and failure modes)
3	To measure **economic** impact of each MFF concept against a do nothing option
4	To assess the impact of MFF concepts on the interactions between civil and **military** traffic
5	To assess the **capability** of MFF concepts to cope with future traffic growth
6	To assess the **environmental** impact of each MFF concept compared to a reference case
7	To assess the airspace management **transition** when MFF concepts are applied (transition between geographically contiguous airspaces)
8	To check the appropriateness of the proposed ATM **architecture**

In theory, Validation Objectives could remain stable and be a reference during the whole duration of the project. However, during execution of large projects new requirements and constraints can come in, and unexpected issues pop up, influencing the original Validation Objectives. The MFF project was not an exception. Constrains in budget and time, new information and unexpected issues influenced the original Validation Objectives. For this reason a maintenance procedure, involving all the relevant project staff and appropriate management levels, was set up to revise and re-formulate Validation Objectives when needed.

IV - The Validation Process in MFF

According to the MAEVA methodology the identification of the Validation Objectives should be followed by the development of a Validation Plan [14]. The Validation Plan should identify a set of Validation

Exercises and their interaction and timing. Examples of Validation Exercises are Studies, Model Based and Real Time Simulations, Cockpit Simulations, Flight Trials, Safety Cases. The results have to contribute to the information required by the Validation Objectives. These Validation Exercises should be identified and designed considering the maturity of the concepts under study, the Project and Validation Objectives, and the output of the Validation Exercises already performed. Figure 2, gives an overview of the MFF Validation Process.

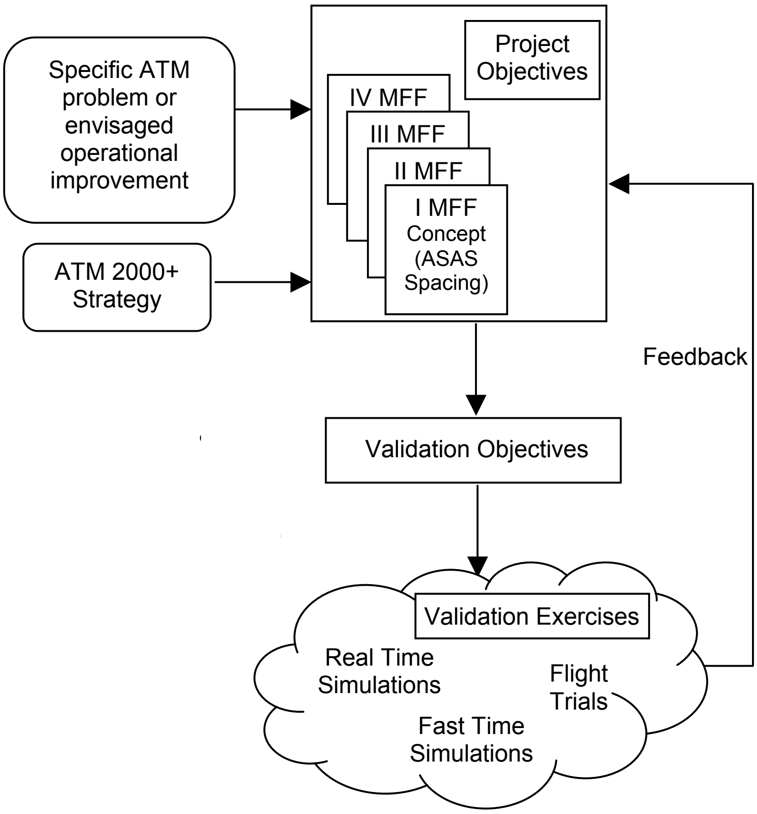

Figure 2 -Theoretical MFF Validation Process overview

However, as described in the previous Section, the most important Validation Exercises were already identified and planned in MFF, and were included in the list of the technical activities of the project. In particular, the project plan at the start of the project included already sets of Fast Time Simulations, Real Time Simulations and Flight Trials and defined an overall schedule for these Validation Exercises. Then, the focus of the validation team was on specifying the scope of these Validation Exercises, integrate them with new ones to ensure that the maximum amount of information for the Validation Objectives were collected, and finally support the integration of results. This was done through the activities listed below and described in more detail in the rest of this Section.

1. **Scoping the Validation Exercises**. The aim of this activity was to define exactly what should be measured during the Validation Exercises in order to provide complete information, while avoiding useless duplications. For example, specify what should be measured during a Real Time Simulation to evaluate if the controller workload will increase because of the concept under study, and how many Validation Exercises should be dedicated to this scope, in order to provide information that are complete enough and at the same time not redundant.

2. **Maximise coverage of Validation Objectives by planned Validation Exercises**. The aim of this activity was to verify if the combination of the planned Validation Exercises will be able to provide all the information required by the Validation Objectives, considering all the assumptions and the different operative scenarios of the Validation Exercises. The planned Validation Exercises were

completed with additional ones to achieve the maximum possible coverage given the project schedule and the budget constraints.

3. **Integrate results**. The aim of this activity was to integrate the output of the different Validation Exercises, sometimes obtained under different assumptions or using different operational conditions. This was done together with the different teams involved in the execution of the Validation Exercises, promoting the share of feedback and the consensus around the results provided by the different teams.

Scoping the Validation Exercises. MAEVA has shown that it is difficult to demonstrate that the Validation Objectives are achieved, and for this reason the high level objectives have to be decomposed into Detailed Validation Objectives. The Detailed Validation Objectives have a direct influence on the Validation Objectives and, being more detailed, are more easily measurable. The measurement of an element through its decomposition into more measurable entities is a common approach in science, and a very similar approach has been successfully used, for example, in software engineering to measure the quality of software [2]. In MFF this process of decomposition was repeated several times and resulted in a hierarchical structure of objectives (tree model). As an example, in Table II, the first MFF validation objective "To evaluate if controllers and pilots are able to operate effectively using the new procedures and tools" has been decomposed into several Detailed Validation Objectives including "To evaluate the influence of the new system on controllers and pilots workload". That Detailed Validation Objective was further decomposed into several second level Detailed Validation Objectives, including "To evaluate if the overall controller and pilot workload is within tolerable limits".

Table II

<table>
<tr><th>Validation Objective</th><th>Detailed Validation Objective (I level)</th><th>Detailed Validation Objective (II level)</th></tr>
<tr><td rowspan="3">Controllers and pilots able to operate effectively using the new procedures and tools</td><td rowspan="2">Influence of new procedures and tools on controllers and pilots workload</td><td>Overall controller and pilot workload is within tolerable limits</td></tr>
<tr><td>Other detailed Validation Objectives of II level of decomposition ...</td></tr>
<tr><td>Other detailed Validation Objectives of I level of decomposition ...</td><td>Other detailed Validation Objectives of II level of decomposition ...</td></tr>
</table>

The decomposition of objectives ends with the identification of measurable indicators, that represent the leaves of the leaf in the tree model. Indicators can provide information about the lower level of the Detailed Validation Objectives through measures taken during the Validation Exercises. For example, in table III, the Detailed Validation Objective "To evaluate if the overall controller and pilot workload is within tolerable limits" is associated to two indicators of the workload perceived by controllers and pilots.

Table III

Detailed Validation Objective (II level)	Indicators	Metrics
Overall controller and pilot workload is within tolerable limits	Workload perceived by controllers	ISA
	Workload perceived by pilots	Questionnaire about workload perceived by pilots

These indicators can be evaluated through measures taken during the Validation Exercises (e.g. ISA during the real time simulation and questionnaires about workload perceived by pilots during flight trials) as shown in the figure 3.

The evaluation of objectives at a lower level of the hierarchy should allow the evaluation of the objectives on the next level up the hierarchy. An iterative approach to evaluation will, therefore, move up the hierarchy. In practice, all leaves of the tree can be measured and, therefore, assessed. Their assessment allows the assessment of the father, the assessment of the father and the other objectives at the same level allow the assessment of the 'grandfather' and so on.

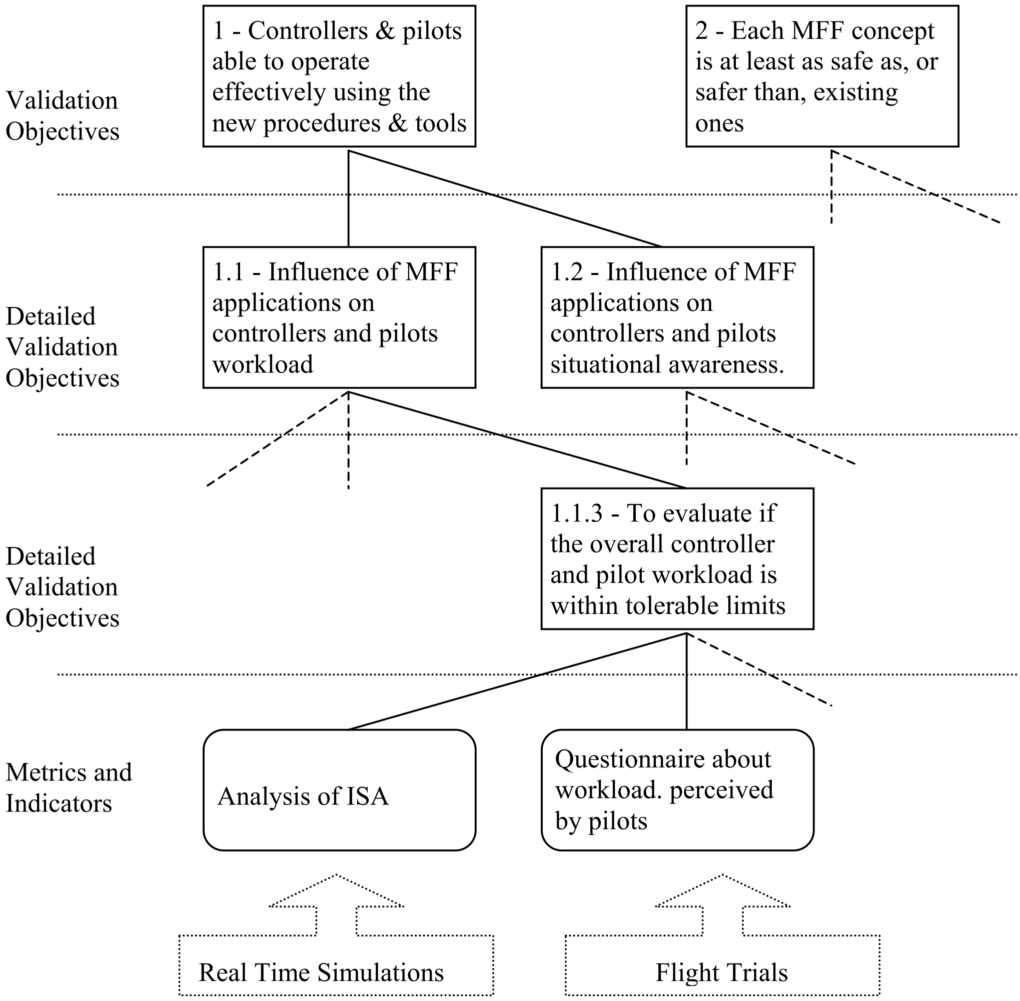

Figure 3 - Identification of Metrics

Maximise coverage of Validation Objectives by planned Validation Exercises. Each Validation Exercise has its own characteristics and specific measurements. Model Based Simulations are more oriented towards efficiency, and capacity, Real Time Simulations are more oriented towards human factors evaluations, operational issues and hazards, while Flight Trials are more oriented to technical issues and human factor evaluation in the most realistic of the environments, and so on. In addition, the differentiation of the sources of evidence is recognized as the best practice of any type of scientific investigation, because each source of evidence is prone to specific observational errors that can bias the quality of the results. The differentiation is especially important in a dynamic domain like ATM, which is complex and multifaceted by the integration of human, procedural and equipment components for the control and management functions. Only a well organised and integrated combination of Validation

Exercises can ensure an optimal coverage of the Validation Objectives, ensuring that all the necessary information has been collected.

The achievement of the Validation Objectives had to be investigated for the different MFF applications (Free Routes, ASAS Spacing, ASAS Separation and Airborne Self Separation Assurance) and under the different operational conditions that are considered by the MFF reference scenario (e.g. different traffic levels, en route vs. approach to terminal area, etc.). A specific indicator can provide information that are limited to a specific application (then the measure needs to be repeated for the other applications to achieve a complete coverage) or that are valid for all the applications. Analogously the indicator can be of value only for the specific scenario (e.g. geographical area, sectors, phase of flight, traffic sample) under which the measure has been taken or be of value also for other possible scenarios.

The Validation Team ensured that the combination of the Validation Exercises was able to provide all the information required by the Validation Objectives, considering all the applications, assumptions and the different operative scenarios of the Validation Exercises. Specific forms were used to summarise the coverage achieved for each Validation Objective. An excerpt of one of these forms, related to Validation Objective 1 is shown in figure 4.

Objective 1

Validation Objective	Detailed Validation Objective (I level)	Detailed Validation Objective (II level)	Validation Exercises	Indicators	Metrics	Applications	Scenarios	Other limitations	Comment
1 - Controllers & pilots able to operate effectively using the new procedures & tools	1.1 - Influence of MFF applications on controllers and pilots workload	1.1.1 - To evaluate if the overall controller and pilot workload is within tolerable limits when MFF applications and tools are introduced	Model Based Simulation	Quantitative controller workload	Average Simulated Workload per Hour per Sector	A1	AENA MBS		
			Real Time Simulation 3	Quantitative controller workload	Analysis of ISA, RT, telecomm and tactical instructions. Analysis of usage of MFF tools under differing traffic levels	A3	A3 ASAS S&M Rome fixed route arrival situation	Simulation design similar to RTS2 (statistical comparison of ORGS + scenarios) Close cooperation with COSPACE Full military participation	ENAV Rome Simulations
			Real Time Simulation 3	Qualitative controller workload	Subjective self-assessment of WL compared between organitation (PEQ) Expert qualitative assessment of WL (Ob., VA)	A4	A4 ASAS Procedures Malta East/Athens Sectors Fixed Route	Design will ensure as much as possible subjective feedback as possible on all A4 procedures No military involment	ENAV GreeK/Malta Simulation
			Real Time Simulation 3	Qualitative pilot workload	Post-run questionaire, observation, debriefing	A5	A5 transition + intent simulation Eastern Med split North/South FFAS to south, MAS to north FX & Free Route MAS FX route below FL285	Benefit of down-linked TCP (intent) information displayed to MAS ATCO To validate need for MAS/FFAS transition zone. No military participation	LFV A5 transition + intent simulation
		1.1.2 - To evaluate if the controller and pilot is able to work efficiently when a transient workload peak occurs. This is related to usability of the new applications	Real Time Simulation 1	Controllers subjective assessment of workload peaks	Questionnaire, HF experts qualitative assessment (Ob., VA) SME comments (Deb.)	A3	All		

Figure 4 - Example of the forms used to visualise Validation Objective Coverage

Verification of coverage achieved during the project leaded to the identification of missing information and to integration of the original validation plan with new Validation Exercises defined by the team in charge of the Validation Process.

Another element that was considered to obtain an optimal coverage was the evolution of the MFF Concepts and Procedures. These Concepts and Procedures were refined, improved and consolidated during the project. The different Validation Exercises were distributed during the project lifecycle taking this improvement and consolidation process into account. As soon as concepts and procedures were refined and stable, the project used Validation Exercises that were inherently more detailed and realistic, starting from Model Based Simulations, through the Real Time Simulations to the Flight Trials, with a highly iterative process of concept refinement and validation. This included several cycles of Model Based Simulations, three sets of Real Time Simulations, three Safety Cases, and an extensive set of Flight Trials, several additional Other Validation Exercises such as workshops eliciting expert opinions and specific dedicated studies and simulations. Cockpit Simulations were used in support to both Real Time Simulations and Flight Trials. The sequence of these Validation Exercises is shown in fig. 5.

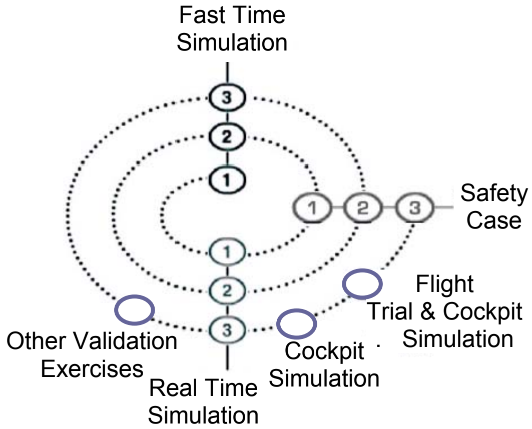

Figure 5 - The iterative cycle of Validation Exercises

However, the evolution of the MFF Concepts and Procedures posed a major problem of applicability and transferability of results. In some cases, the results obtained by Validation Exercises, that used the first versions of Concepts and Procedure, were no less applicable when these Concepts and Procedures were revised and refined, and it was very difficult to define criteria to evaluate if these results were still valid.

Integrate results - The evaluation of a given Validation Objective may be based on a number of results from a set of different Validation Exercises. These results should be aggregated and used to evaluate the different levels of the Detailed Validation Objectives up to the Validation Objectives, with a bottom-up approach, as shown in fig. 6. No guidance is given by MAEVA for this aggregation of results, and for the evaluation of the achievement of the Validation Objectives on the basis of the Validation Exercise results.

In MFF a Validation workshop was held to combine and integrate these results. The workshop was organised by the Validation Team and involved all the teams in charge of the Validation Exercises and a representative group of actors involved in the Validation Exercises (e.g. pilots, and controllers), with the purpose of coming to a consensus view on the results. Structured reports produced by the Validation Data Repository (see next Section) were distributed well before the workshop to the participants. These reports contained a synthesis of the results of all the different Validation Exercises, and were completed with a preliminary view of the Validation Team for the results aggregation. At the workshop the results were presented and discussed in plenary sessions, co-ordinated by the Validation Team, arriving to a vision of the Validation Results shared by all the relevant actors who participated to the Validation Process.

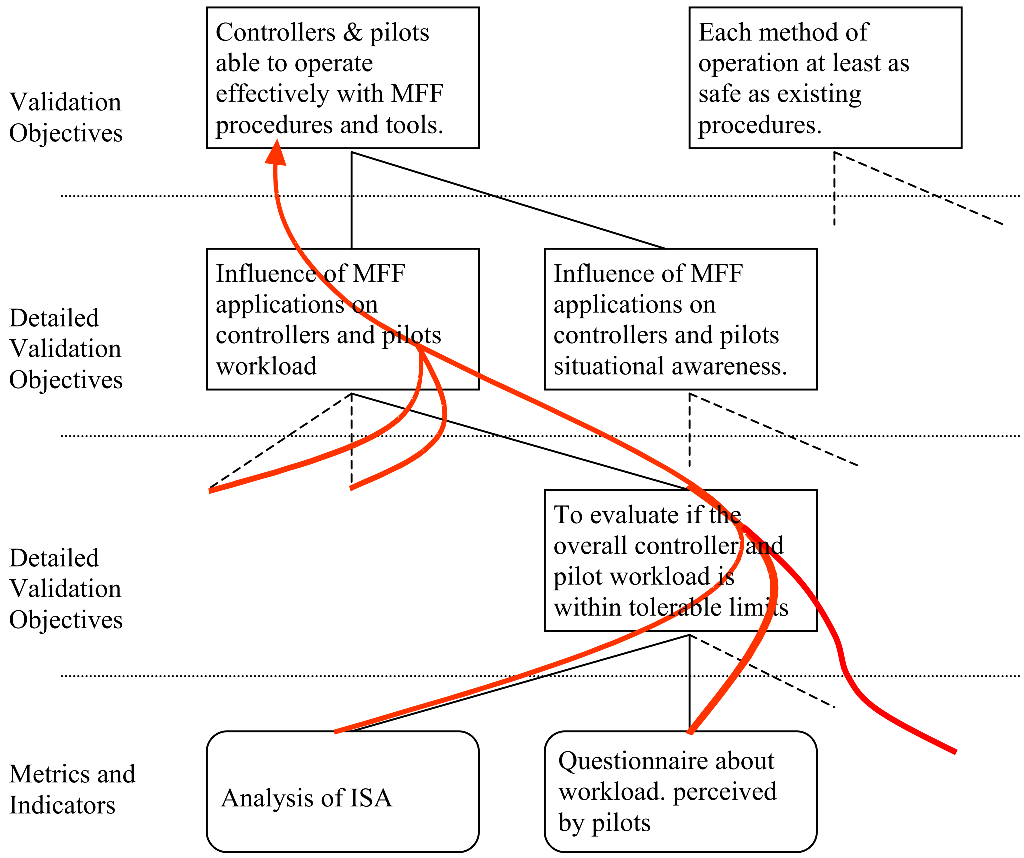

Figure 6 - Integration of results

V - Use of the Validation Data Repository in MFF

The volume of information involved in the whole Validation Process required a system for information management. The whole Validation Process was supported by the use of the Validation Data Repository (VDR), which holds the results and conclusions from all the MFF Validation Exercises mapped to the relevant Validation Objectives and organised according to MFF Operational Concepts. This enabled structured reports to be produced throughout the project, and especially as preparatory material for the workshop.

VDR is an information management resource managed and run by Eurocontrol for the ATM R&D community [10]. It is a repository of information about Validation Exercises with their objectives, methods, design, metrics, results and findings. This information is mapped to standard reference lists to enable sorting, filtering and searching by a number of parameters such as Key Performance Areas, Operational Improvements and Validation Techniques. It was developed in close liaison with the development of the validation methodology under MAEVA and is the recommended validation information tool by the E-OCVM [6]. MFF provided a valuable opportunity for the VDR project to work closely with a major ATM validation activity and determine the practical realities of validation information management and thereby identify how the VDR could be enhanced to improve the support to projects of this type in the future.

The first step was to capture the Validation Objectives hierarchy to provide a framework against which the context of the validation exercises could be mapped. As exercises were performed the detailed reports were used as the main source of information for capture.

VDR contains all the results and findings of MFF Validation Exercises as reported in official documents released by the MFF project, which are all Model Based and Real Time Simulations, Flight Trials, Safety Cases, environmental studies, economic appraisal, architecture validation and the results of the final validation Workshop. The official documents as released are accessible directly by hyperlink from the relevant information in the VDR. Specifically, each MFF Validation Exercise has been recorded in the VDR:

- With details of the validation scenarios and related scenario parameters that were validated;
- Linked to the specific MFF Operational Concept applications, e.g. Free Routes, being validated;
- Linked to the relevant entries in standard validation design reference lists, i.e. technique (real time simulation, flight trial etc.), methods (statistical data analysis etc.) and tools (data collection and analysis tools, validation platform etc.);
- Linked to the relevant entries in the MFF Validation Objective hierarchy;
- With details of findings in terms of results, conclusions and recommendations and the links between them;
- With links between the conclusions and the related objective in the MFF Validation Objective hierarchy;
- With a hyperlink to the original source document of the validation findings, typically a validation report.

These information sets and links between them are summarised in the diagram of fig. 7.

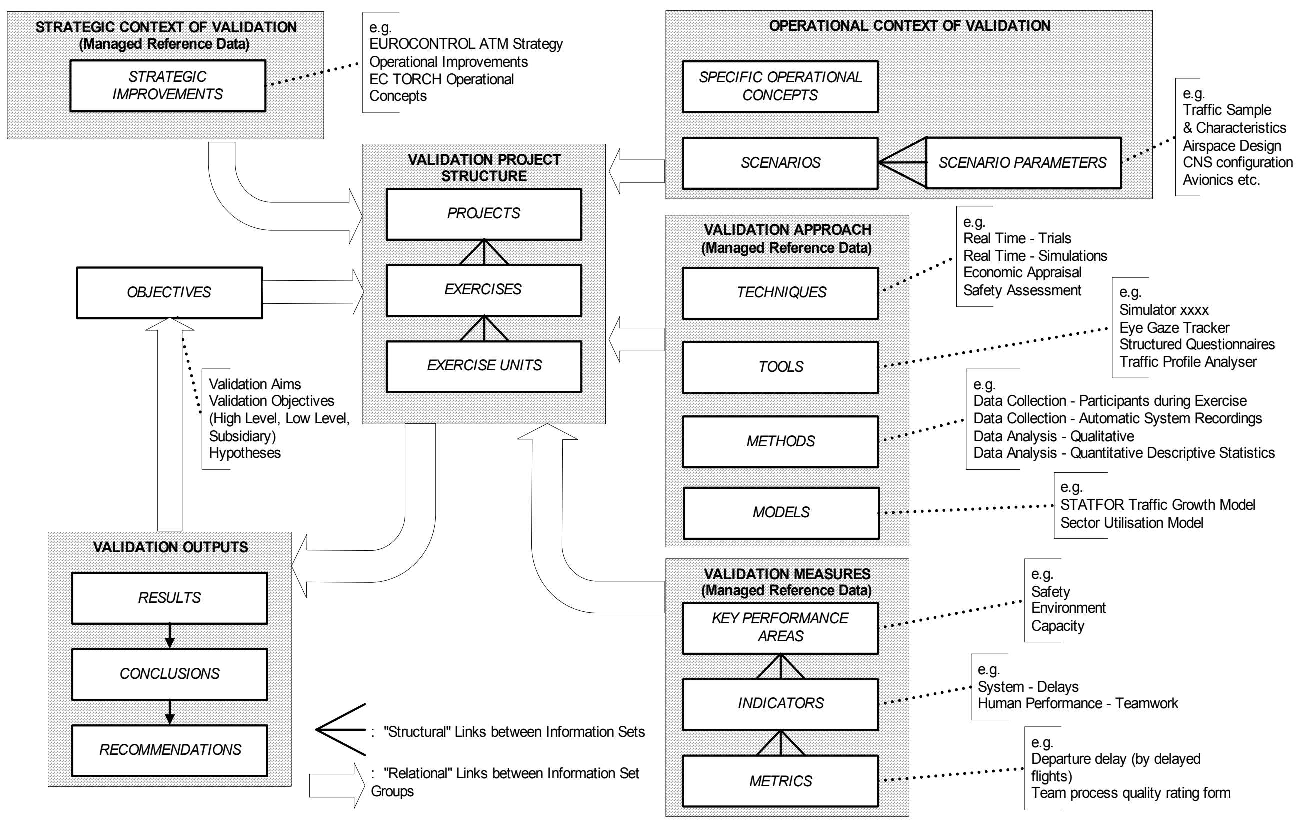

Figure 7 - VDR Information Set and Relationships Summary

VI - Feedback from the application of the Validation Process

Several resources of the MFF project were reserved for validation, and in particular a whole project working area was dedicated to the definition of the validation activities, with the opportunity to develop, evaluate and refine the Validation Process presented in the paper. This Validation Process represented an essential support for organising the Validation Exercises and for integrating their results, offering most of the information required by the Validation Objectives and evidencing where these information could not be collected, or were not trustable enough, or were limited to specific applications and operational conditions.

The process adopted a participative approach in which the different members of the project teams were involved in all the phases of the Validation Process relevant for them. Table IV shows the participation of the different teams in the main phases of the Validation Process. This participative approach, implied an extra cost in terms of effort to the project, but increased both the consensus around the project results and the results credibility, because all the relevant actors had the opportunity to offer their feedback and contribute to the verification and refinement of the results.

Table IV

Main phases of the Validation Process	Project teams involved
Definition and refinement of the Validation Process	Validation Team
Identification of the Validation Objectives	Project Management with the support of the Validation Team
Decomposition of the Validation Objectives in Detailed Validation Objectives	Validation Team together with the Project Management team and with representatives from the teams in charge of the different Validation Exercises
Maintenance of the Validation Objectives	
Assignment of Detailed Validation Objectives to Validation Exercises	Validation Team together with the representatives from the teams in charge of the different Validation Exercises
Identification of indicators and metrics for each Detailed Validation Objective and Validation Exercise	Validation Team together with the team in charge of the Validation Exercise concerned
Verification of coverage	Validation Team with support from the teams in charge of the different Validation Exercises
Production of Validation Exercise results	Teams in charge of the different Validation Exercises
Workshop and integration of results	Validation team together with the Project Management team, representatives from the teams in charge of the different Validation Exercises, and from all the actors who collaborated to the Validation Exercises (e.g. controller and pilots, technical and architectural experts, etc.)

An additional, unexpected advantage, offered by the process, and in particular by this participative approach, was the opportunity for communication, inside the project, about the validation work. The definition and the evaluation of the different phases of the Validation Process required an increased interchange of information between the different project teams and offered the opportunity to share the aims and the progress of validation, fostering interactions, especially between the teams in charge of the different Validation Exercises.

The use of VDR was essential to manage the high volume of information involved in the Validation Process, and facilitated the comprehension of objective hierarchy, of the contribution of the different Validation Exercises, and of coverage of Validation Objectives achieved. In addition, the presentation facilities of VDR enabled easier collation, and presentation in deliverables, of validation results grouped by Validation Objectives and Applications, and facilitated the delivery of preparatory material for the workshop and the final results integration.

The positive feedback listed above are counterbalanced by some negative aspects emerged during the definition and application of the process. The Validation Process proposed in MAEVA adopts a simplistic, theoretical view of the project lifecycle with distinct, sequential project phases. The reality of the MFF project was more complex and, sometimes driven by constraints. For example, we have already seen that most of the Validation Exercises such as the Real Time Simulations and the Flight Trials were already identified and planned and included in the list of the technical activity of the project before the identification of a validation strategy and plan. An additional example is represented by the feedback provided by the Validation Process. According to MAEVA the feedback should be used to improve the Operational Concepts during the project lifecycle as shown in figure 2. But, this was very difficult to achieve in reality. The results of the different Validation Exercises were consolidated and integrated only at the end of the process during the validation workshop, and only some preliminary results could be used to provide feed-back to the teams in charge of the refinement of the Operational Concepts.

The MAEVA guidelines [14] provide guidance for some phases of the Validation Process, but there is a significant lack of explanatory examples, and of feedback from the application of MAEVA to real projects. In addition, there are indications for the decomposition of Validation Objectives, but there is no guidance to integrate the results provided by the different Validation Exercises. We have already seen that the evaluation of a given Validation Objective may be based on a number of results from a number of different Validation Exercises. These results should be aggregated and used to evaluate the different levels of the Detailed Validation Objectives up to the Validation Objectives, with a bottom-up approach, as shown in fig. 6. MAEVA does not provide indications for this aggregation work. In MFF, this was done through the validation workshop but only from a qualitative point of view, and there was limited quantitative evidence supporting the conclusions.

VDR is flexible enough to accept even significant changes to the information reference structures, during the project, such as, changes to the Concepts and Procedures, or to the Project Objectives. However when these changes happen, the particular organisation of the information makes particularly difficult the activity of transferring and mapping, into the new structure, the results of the Validation Exercises performed before the changes. There are also some limits in the data presentation facilities offered by VDR. These are adequate for the technical teams and for the preparation of technical reports, but not explicative enough and too disaggregated for those who have not been involved in the project and are not aware of its organisation. A number of development initiatives related to reducing the complexity of data capture/maintenance and improving the data presentation facilities have been undertaken by the VDR project as a direct result of the experiences and feedback from the MFF project.

VII - Conclusions

The paper described how the validation approaches proposed in recent validation research initiatives, and in particular in MAEVA, have been modified, integrated and applied in the MFF project. The resulting process has been very successful, especially considering all the imposed constraints, and the positive aspects outperformed the negative ones, because, through this process, the MFF project could collect most of the information required for the validation of the project results. The VDR proved to be a valuable validation information management tool for supporting the coordination of the project and it has been further developed as a result of the direct feedback and experiences of the project. MAEVA has recently been revised and incorporated in E-OCVM. The experience from the use of a MAEVA based Validation

Process suggests a wider adoption of E-OCVM at the European level, that could offer a better overall view of where the research domain is with the validation of research concepts in ATM. This will be possible only if results are comparable because obtained using similar methods, comparable operational environments and well defined and justified assumptions.

However, at the project level, the support provided for some of the Validation phases (e.g. integration of results) is still not adequate, and there is a need for more explanatory examples and feedback from real life applications. Some areas deserve further investigations and in particular the notion of coverage should be better understood, especially in relation with the maturity of the operational concepts under study.

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