



**EUROPEAN
Operational Concept
Validation Methodology
(E-OCVM)**

“Establishing fitness-for-purpose”

*“The iterative process by which the fitness-for-purpose of
a new system or operational concept being
developed is established”*

EUROPEAN
Operational Concept
Validation Methodology

E-OCVM
Version 2

EUROPEAN AIR TRAFFIC
MANAGEMENT PROGRAMME



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Abstract			
<p>This document provides the European Operational Concept Validation Methodology (E-OCVM). It has emerged over more than 10 years from experiences gained in many European co-operative ATM R&D activities, involving R&D institutes, ANSPs and industry mostly in the framework of EC and EUROCONTROL funded projects.</p> <p>The E-OCVM aims to provide a common approach to all projects contributing to the validation of operational concepts from early issues identification to full pre-operational validation, the stages prior to industrialisation and operational introduction. This Operational Concept Validation Lifecycle may take up to several decades. Many different organisations may need to contribute over time.</p> <p>The Validation Forum aims to bring together all projects that contribute to the validation of the future European ATM concepts in order to exchange experiences and best practices and to further extend and improve the document.</p>			
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JPB message on validation

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1

Message from the EC/EUROCONTROL Joint Programme Board (JPB) on validation

The JPB has agreed on the following actions:

To increase the awareness of Operational Concept Validation Methodology (OCVM) and Validation Data Repository (VDR):

To improve the transfer from R&D to operations within the collaboration between the EC and EUROCONTROL in the ATM Master Plan and ACARE context, a common ATM validation methodology and support for ATM validation information storage and dissemination is needed. As a result of a common effort of Air Traffic Service Providers, R&D Institutes and Industry and supported by EC and EUROCONTROL an agreed Operational Concept Validation Methodology (OCVM) and a Validation Data Repository (VDR) are now available to the ATM community.

To use the recommended Validation Methodology:

The Joint Programme Board in its meeting on 24 January 2005, required the application of OCVM and the use of VDR by all ATM related projects in particular within the collaboration between the EC and EUROCONTROL in the ATM Master Plan and also along the ACARE Strategic Research Agenda SRA-2. All new projects concerned shall reflect the use of OCVM and VDR in their plans and prepare for the necessary effort. In addition, the existing projects are invited to consider the use of the OCVM and the VDR.

To create a Validation User Group:

The EUROCONTROL Agency is tasked to maintain the OCVM and VDR. EC will continue to support the further development of OCVM and VDR.

In order to capture all relevant advice/requirements coming from practical experience in applying the OCVM and using the VDR, EUROCONTROL supported by the JPB, will organize a Validation User Group. All project leaders of ATM-related projects are invited to take part in such a Group.

Access to the OCVM and VDR and registration for the Validation User Group have to be made via the web site www.eurocontrol.int/valug.

Brussels, 11 April 2005

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PRINCIPAL CHANGES

PRINCIPAL CHANGES FROM VERSION 1

Improvements to consistency of language and terminology to support preparation of training material;
Increased emphasis on identification of ATM needs and constraints to current performance as pre-requisite information essential for validation;
Consolidation of sub-steps 2.6 to 2.9 in Step 2 "Determine Exercise Needs."

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1. Foreword

1.1 History

Since the mid 1990's the lack of clear and understandable information ("business case") to support decision making on implementation was generally perceived as being the root of the problem of limited transfer from R&D to operations, sparking the "Validation Debate". The European Commission (EC) provided a platform for that debate bringing together industry, R&D organisations, Air Navigation Service Providers (ANSPs) and the EUROCONTROL Agency in a Concerted Action on Validation of ATM Systems (CAVA).

Following CAVA, the EC project Master ATM European Validation Plan (MAEVA, Ref: 1) provided a forum for the continuation of the discussion and an intensified co-ordination between the EC and the Agency. Building on an earlier Agency proposal MAEVA provided the first version of the Validation Guideline Handbook (VGH) in April 2002. In June 2002 the Agency made its Validation Data Repository (VDR, Ref: 2) publicly available. Both developments, VGH and VDR, have also been coordinated by the Agency with the US FAA under the umbrella of the FAA/EUROCONTROL co-operative R&D effort. A result of the ongoing FAA/EUROCONTROL collaboration is the FAA/EUROCONTROL Operational Concept Validation Strategy Document (OCVSD) (Ref. 3). Both E-OCVM and OCVSD are consistent and complementary.

The VGH was broadly disseminated by the MAEVA project. The Agency made it a reference document in its EATM Management Handbook. MAEVA organised several fora to discuss VGH and VDR and solicited feedback from the VGH and VDR users. Before MAEVA terminated in May 2004 several new versions of VGH and VDR were produced.

Since then the Agency integrated its own concept development and performance driven approach and EATM Business Model into the VGH resulting in the Operational Concept Validation Methodology (OCVM). The OCVM and VDR were harmonised and support each other. In 2004 the OCVM was broadly reviewed

and further improved by the EC project Co-operative Approach to Air Traffic Services (CAATS).

The "Validation Debate" has finally converged to the European OCVM (E-OCVM). It has reached sufficient maturity to become a reference document in the EC/Agency ATM co-operation. It found also entry into US FAA activities as well as the JPDO NextGen effort. The VDR provides a data structure to support E-OCVM and awareness of the progress of validation. After completion of CAATS, the EC continues to support E-OCVM via the Co-operative Approach to Air Traffic Services II Project (CAATS II, Ref. 4).

1.2 E-OCVM and the EC-EUROCONTROL collaboration in ATM R&D

In order to co-ordinate its ATM R&D activities the European Commission (EC) and the EUROCONTROL Agency have set up the Joint Programme Board (JPB). The JPB consists of high level representatives of both organisations.

In January 2005 the JPB endorsed E-OCVM and made its use mandatory for all projects in the ATM R&D collaboration where applicable.

Although E-OCVM and VDR are results of comprehensive development efforts involving many involved partners, there is also the need to further maintain them and to incorporate experiences of their users. In addition, users of E-OCVM and VDR must be provided with support.

In April 2005 the JPB requested the EUROCONTROL Agency to organise a Validation User Group (VALUG). In 2006 this group evolved into the Validation User Forum (Ref: 5) to ensure wider access to any person with an interest in validation issues. The forum web site explains and advertises the methodology, and enables an exchange of experiences and best practices to further extend and improve the methodology.

1. Foreword

The technical entry point to the Validation Forum is via the EUROCONTROL web site at:

<http://www.eurocontrol.int/valfor>

This Version 2.0 of E-OCVM is endorsed by the Validation Forum Supervisory Group and reflects:

- Improvements to consistency of language and terminology to support preparation of training material;
- Increased emphasis on identification of ATM needs and constraints to current performance as pre-requisite information essential for validation;
- Consolidation of sub-steps 2.6 to 2.9 in Step 2 Determine Exercise needs.

This version therefore incorporates little change from the first version, but aims to clarify and improve readability.

PART I - OVERVIEW OF THE VALIDATION METHODOLOGY

1. Introduction

1.1 The ATM community needs

Assumption: *The ATM industry expects R&D to deliver information on the expected performance of novel ATM concepts that will assist decision makers to determine the most appropriate solutions to be implemented.*

The ATM community is searching for solutions to improve the performance of and/or reduce the costs of the air traffic management service. Forecasts from the EUROCONTROL Performance Review Unit (Ref: 6) show that the ability of the ATM system to support growth will be severely limited if there are no further enhancements to the way traffic is managed.

Principal outputs from ATM R&D to address the ATM community needs are assumed as being:

- **PRODUCT** description – examples in prototype or other form of ATM System enhancements accompanied by specifications, requirements and operating instructions;
- **PERFORMANCE** description - information on the performance and behavioural capabilities of the enhancements

1.2 The ATM R&D response to the ATM community need

Assumption: *ATM R&D will provide information on performance capabilities of novel ATM concepts through the use of a consistent, transparent, methodical approach to design and evaluation.*

The ATM R&D principal business is to develop novel ATM concepts into solutions that address the ATM community needs for improved performance and/or reduced costs (expressed above). These solutions should be described in ways that allow the ATM community to choose between alternatives and then decide what should be implemented, when and how.

In order to choose suitable enhancements for

implementation the ATM stakeholders need information on performance capabilities, potential costs and benefits of R&D generated solutions. Most benefits that ATM enhancements are expected to deliver can be covered by the following performance areas:

- **CAPACITY:** Increased throughput or capacity (airspace and airports);
- **SAFETY:** Improvements in safety rates;
- **ENVIRONMENT:** Assurances that environmental impacts are within internationally accepted norms;
- **ECONOMY:** Improvements in cost-effectiveness of operations (through reduced costs and/or improved efficiency).

In addition to the above ATM performance areas an important element to check is that the changes envisioned by the novel concept are checked for:

- **OPERABILITY:** Usable by and suitable for those who operate the ATM system, e.g. controllers and pilots. Satisfaction of usability and suitability issues lead to operational acceptability.

There are other issues that should be addressed depending on the nature of the ATM Concept being developed, but the above performance areas are generally important. Any solution targeted at a specific performance area will also need to be evaluated for its impact on other performance areas.

This EUROPEAN Operational Concept Validation Methodology is focused on the consistent provision of information on performance capability and operability.

N.B. The SESAR Programme will identify and document Key Performance Areas (KPA) and Key Performance Indicators (KPI) appropriate to ATM and which closely follow ICAO's work on this subject. Further updates to the E-OCVM will take the SESAR work into account.

1.3 The problem space

Assumption: ATM R&D has a poor record in getting solutions to operational implementation because:

- the evaluation process is not consistent, transparent, relevant or appropriate enough to support the decision makers' information needs.

This is generally due to the decision making stakeholders' lack of sufficient assurance in the information provided by R&D to be persuaded in any particular direction.

This approach to operational concept validation focuses on providing a methodology to identify stakeholder information needs and then use these as a main (but not sole) driver for the evaluation of proposed concepts i.e. an 'Operational Concept Validation Methodology'.

It is respected that for an Operational Concept Validation Methodology to be useful it must promote the following principles:

- **Consistency** – using a methodology and providing information on various concepts in a similar format and tested against similar situations (scenarios) helps ensure consistency of the evaluation process;
- **Transparency** – show important issues that have not been tested as well as those that have, and make the information easily accessible (c.f. Validation Data Repository);
- **Relevancy** – has two aspects, relevancy of the concept under development to stakeholders needs and relevancy of the experimentation to the eventual real-world situation where it will be implemented;
- **Appropriateness** – to the key stakeholder information needs. Different stakeholders have different needs in terms of information on behaviour and performance capabilities. These various needs should be addressed by the development and evaluation programmes:

- Showing that a solution 'works' in the most challenging ATM situations will help to show relevancy without testing under all separate national situations;
- Choosing test situations appropriate to the maturity of the concept.

1.4 Operational Concept Validation

Validation as a generic term has wide usage but with a diversity of interpretations. Even in one area, such as system engineering, it may have different characteristics. In particular in software engineering the V-Model is commonly used to address validation and does so along with verification. The V-Model perception of the terms Validation and Verification (V&V), has become dominant in the system engineering community, and has been adopted by other communities such as ATM R&D. However this Operational Concept Validation methodology is based on a premise that the V model is not sufficient for Operational Concept Validation and proposes additional features to address the limitations of the V model.

To assist readers who are familiar with applying the V model the term verification of ATM operational concepts can be described as the process of answering the question **"Are we building the system right?"** (Ref: 6). Using similar terms validation can be described as the process of answering the question **"Are we building the right system?"**

This methodology is focused on validation and does not explicitly address verification issues.

This E-OCVM assumes that at the early stages of development, the operational concept is too vague to be successfully described by a set of requirements (user, operational, technical, safety, etc) which is the fundamental first step of the V model. The E-OCVM is proposing an iterative and interactive process to support development and validation exercises being

1. Introduction

conducted in parallel. The objective is to answer the question “Are we building the right system?” The methodology is based on an iterative process to build stakeholder confidence that an operational concept will satisfy their various needs (a looser term than requirements). The methodology proposes a model where stakeholder confidence is obtained by providing evidence of an operational concept’s fitness for purpose. Principal outputs of the application of the E-OCVM are stable and sufficiently detailed operational requirements to support application of the V-Model in further development of the system.

For ‘concept validation’ this document uses the following perception of Operational Concept Validation:

“The iterative process by which the fitness-for-purpose of a new system or operational concept being developed is established”

Validation can also be defined as the process of answering the question **‘Are we building the right system?’**

Verification can be taken as answering the question **‘Are we building the system right?’** (Ref 6). This document only addresses ‘validation’

Operational Concept Validation should support the process whereby the many stakeholders eventually should come to a decision to either:

- Continue development to a state where implementation is a clearly acknowledged next step;

Or

- stop or substantially modify developments due to some inadequacy of the overall performance or behaviour.

‘Operational Concept Validation’ should be objective and transparent in order to support the decision

making process where the different stakeholders have different information needs and sometimes conflicting requirements.

To support ‘transparency’ there is a need for the availability of more information than a ‘final report’ would provide:

- All evaluation scenarios and assumptions should be made available;
- Checks for unforeseen or negative side-effects on the ATM system should be made apparent;
- Prototypes of different aspects of the intended system should be available and documented.

Where applicable, stating that the system has a negative impact, or that there still remains a high level of risk, is as valid as stating where a system has a positive impact.

Issues to be addressed include:

- Alternative solutions;
- Resource requirements;
- Training;
- Technology performance;
- Technology availability.

Operational Concept Validation naturally encompasses the need for information about safety issues. There are two reasons for this:

- The first is simple - safety is the prime concern of ATM in all cases;
- The second is that safety has a direct or indirect influence on all the remaining objectives. For example, a negative impact on safety would adversely impact all other strategic objectives such as capacity and economy.

2. European Operational Concept Validation Methodology Overview

The validation methodology described here includes three aspects of validation that, when viewed together, help provide structure to an iterative and incremental approach to concept development and concept validation:

- The **Concept Lifecycle Model** facilitates the setting of appropriate validation objectives, the choice of evaluation techniques, shows how concept validation interfaces with product development and indicates where requirements should be determined;
- The **Structured Planning Framework** facilitates programme planning and transparency of the whole process;
- The **Case-Based Approach** integrates many evaluation exercise results into key 'cases' that address stakeholder issues about ATM performance and behaviours.

2.1 Concept Lifecycle Model

Operational Concept Validation (evaluating the fitness-for-purpose of a concept) and concept development (the design and construction of hardware, software, working procedures and human/machine interface) are two aspects of the process of changing concept ideas into reality that cannot be separated.

An ATM Concept takes time to develop into an application and the validation process must allow for this 'maturing'. The Concept Lifecycle Model aims to create a structure for the concept validation that also accounts for the concept development needs. It describes milestones in the development of a concept where fitness-for-purpose should be examined to avoid continued development without an indication of clear benefits or progress.

The following lifecycle model is taken from the work of the FAA/EUROCONTROL Action Plan 5 Validation and Verification Strategies group. It is documented in the Operational Concept Validation Strategy Document (Ref: 3)

Figure 1 describes a simple lifecycle progression through six phases from the identification of a need to improve ATM performance (V0) to implementation of a solution addressing the ATM need (V5). The iterative aspect of the process is not represented in this diagram. At each of the phases the validation scope is likely to mature in line with the advancing maturity of the concept. As the concept becomes more mature, the validation activity must become more rigorous and realistic. Validation Exercises may be larger and the scope and objectives of these exercises and their objectives are more mature.

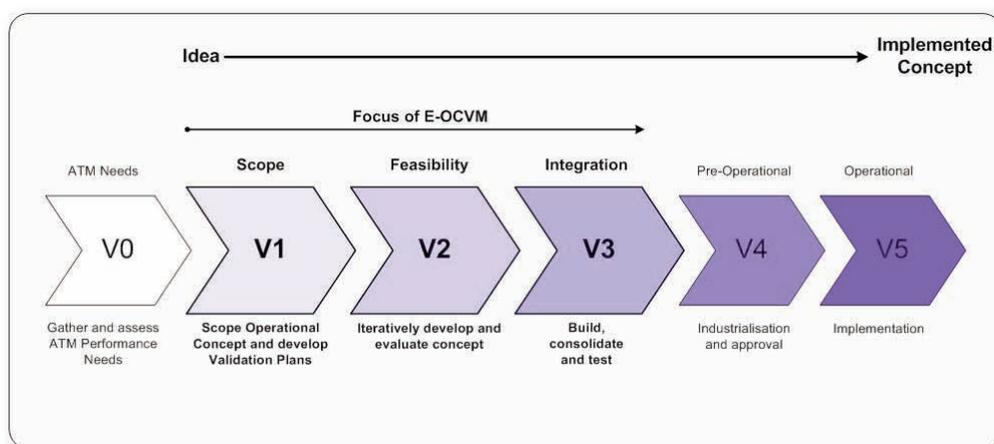


Figure 1: The Concept Lifecycle Model

2. Operational Concept Validation Methodology Overview

The 6 phases of the Concept Lifecycle Model are:

- V0 ATM Needs** – As a prerequisite of concept validation, the ATM performance needs and barriers must be identified. To complete the validation of the concept, the concept must show that it can alleviate these barriers enough thus enhancing ATM performance to the anticipated required level.
- V1 Scope** – The phase where the concept should be described in sufficient detail to enable identification of the potential benefits mechanism (i.e. the change to systems and/or operations that will enable a known barrier to be alleviated). Some aspects of the concept will be unknown or unclear at this stage. They may exist as a number of options to be assessed during the further validation process.
- V2 Feasibility** – The phase to develop and explore the concept until it can be considered operationally feasible. During this phase system prototypes will be used that make assumptions about technical aspects in order to avoid system engineering which can be costly and lengthy. Aspects that should be focused on are operability and the acceptability of operational aspects. It is during this phase that operational procedures and requirements should become stable. The number of iterations depends on the complexity of the concept and how often unexplained situations occur that need to be explained. At the end of this phase HMI, Operating procedures (for normal and key non-normal conditions) and phraseology should be thoroughly tested. This stage will establish the behaviours of the new system.
- V3 Integration** – The phase to integrate any required functionality into pre-industrial prototypes. Engineering processes can be explored to provide experience that will be useful to building the end-system. This phase is focused on integrating operating procedures by using realistic scenarios that are representative of what the concept must

be able to manage in the target end-system. The focus is therefore on system level behaviour, performance and establishment of standards/regulations necessary to build and operate the required technical infrastructure. This work will enable costs and benefits to be clearly identified and provide information about the potential performance of the overall ATM system.

- V4 Pre-Operational** – Pre-operational preparation takes place during this phase. Pre-operational prototypes will be transformed into industrial products ready for implementation and all institutional issues concerned with procedures approval should be addressed (Out of direct scope for R&D).
- V5 Implementation** – This is the phase when products and procedures are combined to create an operational system at a specific site. Implementation is a complex and risky procedure and it can be expected that many pragmatic ‘fixes’ will be required to complete implementation successfully. (Out of direct scope for R&D).

The ‘Concept Validation Methodology’ is most applicable to the phases V1, V2 and V3 of the Concept Lifecycle Model. V0 is considered as pre-requisite information for validation to commence. During the later phases of Pre-operational (V4) and Operational (V5) different methodologies than those proposed here will be required (e.g. The V model).

2.2 Structured Planning Framework

The Structured Planning Framework is presented in a numbered list format – a stepped approach. Each step in the numbered list details the tasks involved in that step as well as a list of inputs and outputs. This approach allows an appreciation of the interaction between steps. Below is a summary of the main steps with a brief description of the principle objectives and tasks to be performed.

0. State Concept and Assumptions:

This initial step outlines where the problem lies, assesses the severity of the problem and understands how the proposed solution aims to resolve the problem. Most of the material in this step should come from sources that exist before a concept validation activity commences. Therefore, much of this activity requires going to those various sources for essential information. This step should be re-examined at the beginning of each new concept lifecycle phase.

1. Set Validation Strategy:

This step initiates the process of identifying the stakeholders, issues, aims, objectives, indicators, criteria and expected outputs of the validation process. All of this information is then formulated into a Validation Strategy which should include a draft plan for the execution of the strategy. At the beginning of each phase of the lifecycle, the information in the Validation Strategy should be reviewed and possibly modified and refined.

2. Determine the Exercise Needs:

This step refines the Validation Strategy and plans the exercises. This step is repeated at each phase of the concept lifecycle and should capture all the detailed exercise needs appropriate to the maturity of the lifecycle phase.

3. Conduct the Exercise:

This step is where the validation exercises are conducted. This step is repeated at each phase of the concept lifecycle where evidence about performance

needs or concept performance capabilities is required. This step may be repeated during a lifecycle phase if further evidence is required. Conduct the studies and carry out the experiments.

4. Determine the Results:

This step is where the results are analysed and reviewed against aims and objectives. This step will be repeated for each lifecycle phase and possibly within a lifecycle phase if multiple exercises are conducted.

5. Disseminate Information to Stakeholders:

This step processes and collates the information from the exercises into 'cases' in order to ensure that information is accessible and understandable to stakeholders. This step is done at the end of each lifecycle phase at the minimum. However unexpected results with an impact on the concept development or the expected performances or behaviours must be prepared and disseminated as soon as possible.

The above steps are shown in more detail in the Figure 2 overleaf. A full description of each sub-step is provided in Part II of this document.

The following chart (Figure 3) shows the main feedback loops that should support review after a validation exercise and at project or programme completion. The question that should provoke a review of the exercise, validation strategy or even operational concept is; 'Was the outcome as expected?' (As identified in Sub-Step 1.3 Validation Expectations)

2. Operational Concept Validation Methodology Overview

	Step	Sub-Step	Name	Output
Lifecycle Phase	0. State Concept and Assumptions	0.1	Understand the Problem	ATM Problem Description
		0.2	Understand the Proposed Solution(s)	Description of ATM Operational Concept(s) or Operational Improvement(s), Typical Operational Scenarios, Alternatives Analysis
	1. Set Validation Strategy	1.1	Identify the Stakeholders, their Needs and Involvement	List of Stakeholders and their Needs, Initial Stakeholder Analysis, Key Stakeholder Questions
		1.2	Identify the existing Information, including Current and Target Levels of Maturity	Statement of Current and Target Levels of Maturity
		1.3	Describe Validation Expectations and outline Cases - outcomes, products, what success will look like	Validation Expectations, Case Based Information requirements
		1.4	Identify Programme Validation Objectives in Key Performance Areas	List of Programme Validation Objectives in Key Performance Areas
		1.5	Establish Initial Validation Requirements and draft Validation Strategy	Initial Validation Requirements, Draft Validation Strategy
		1.6	Select Validation Tools or Techniques	Decision on Tool(s) or Technique(s) to be used
		1.7	Define Validation Strategy	Validation Strategy
	2. Determine the Exercise Needs	2.1	Identify Stakeholders' Acceptance Criteria and Performance Requirements	List of Stakeholders' Acceptance Criteria and Performance Requirements
		2.2	Identify Project and Exercise Validation Objectives	List of Project and Exercise Validation Objectives, Refined Validation Requirements
		2.3	Refine Validation Strategy	Refined Validation Strategy
		2.4	Identify Indicators and Metrics	List of Indicators and Metrics
		2.5	Specify Validation Scenarios	Validation Scenario Specification, Traffic Samples, Platform Scenario Requirements
		2.6	Produce Validation Exercise Plan	Validation Exercise Plan , including Analysis Specification and detailed design
		2.7	Prepare the Platform or Facility	Prepared and Configured Platform
		2.8	Conduct Pre-Exercise Testing and Training	Tested Validation Platform, Trained Participants (where required)
	3. Conduct the Exercise	3.1	Conduct Validation Exercise	Raw Data
		3.2	Assess for Unexpected Effects or Behaviours	Concept Problem Reports
	4. Determine the Results	4.1	Perform Analysis as specified in the Analysis Specification	Analysed Data
		4.2	Prepare Analysis Contributions	Analysis Contributions
		4.3	Prepare Validation Report	Validation Report , Information to Cases, Identification of Validation Strategy Shortcomings
	5. Disseminate Information to Stakeholders	5.1	Disseminate Information to Stakeholders and Decision Makers, using case based approach where available	Dissemination of Information to Stakeholders for review, Stakeholder Review of Results
		5.2	Draw Conclusions and decide on actions. Feedback to Validation Strategy	Conclusions and Actions, Modifications to Validation Strategy

Figure 2: Table showing steps to follow during concept validation

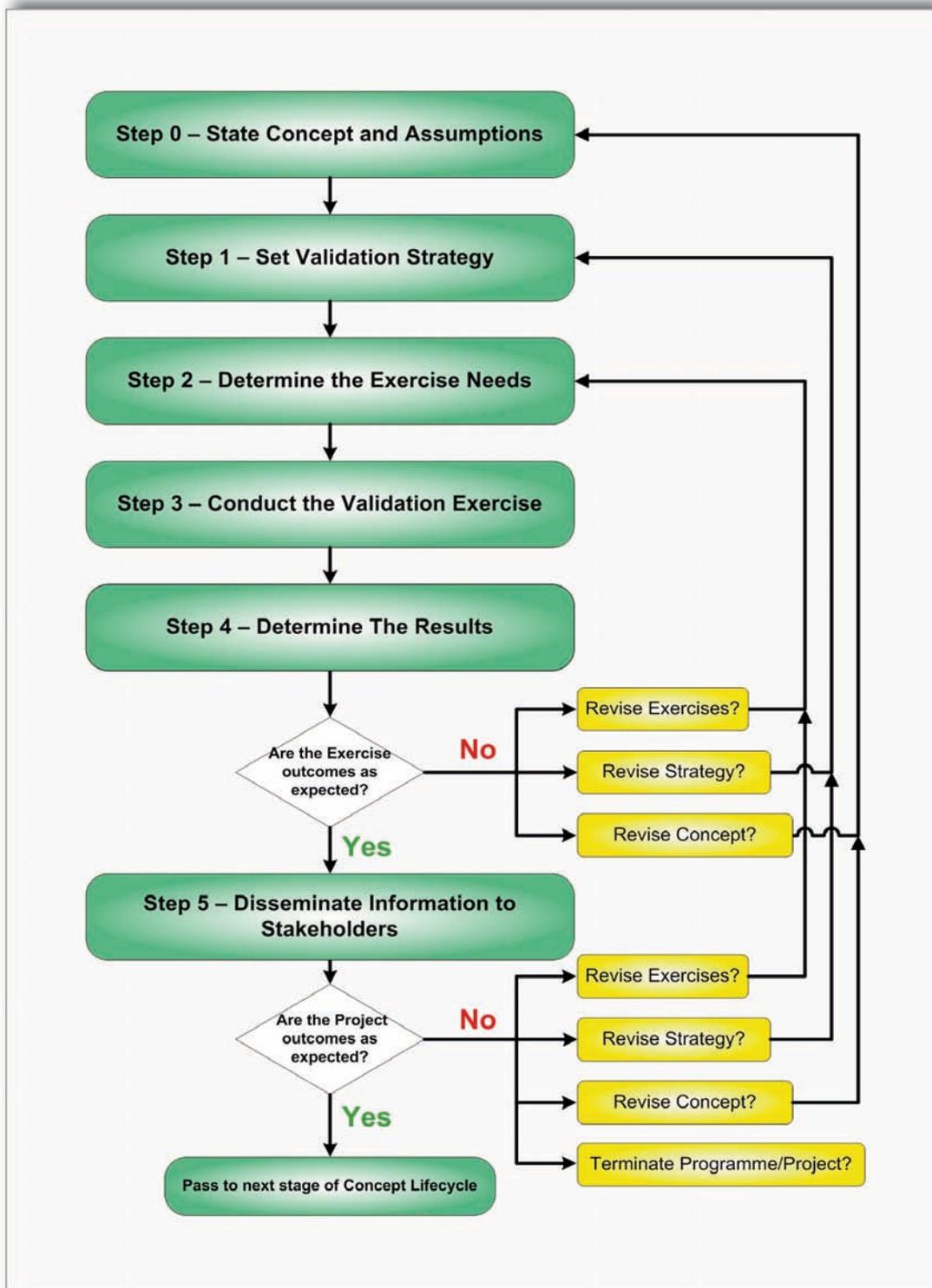


Figure 3 : Flow chart showing review points of exercises, strategy and concept

2. Operational Concept Validation Methodology Overview

2.3 Case Based Approach

This aspect of the concept validation methodology is concerned with providing key stakeholders with targeted information in an easily understood format appropriate to their needs. The information should be pertinent to the performance barrier (as identified in phase V0 of the Concept Lifecycle Model) that the concept intends to alleviate as well as the questions that the stakeholders will need answers to concerning the concept and its performance. Using a case-based approach focused on stakeholder information needs helps to drive information requirements. This supports the shaping of a Validation Strategy.

The objective of using a 'case' is to group information into common aspects in order to describe the potential of the concept under evaluation and thereby support the key stakeholders as they make the investment and implementation decisions. The main cases that should be anticipated are safety, human factors, business,

environmental and technology. Each case will be developed along the concept lifecycle. When required a synthesis of the contents of these cases could be made to address the needs of identified stakeholder groups e.g. operational, safety regulators, ANSP investors, airline investors, ATM technology suppliers etc.

The diagram below (figure 4) represents how stakeholders are central to the validation process. They generate performance needs to start the process as well as requiring information during the development of the concept (structured through the use of 'cases') about how the concept is expected to improve the future ATM system.

The development of the cases requires specific relevant expertise. Methodologies specific to building the content of a case are outside the scope of the E-OCVM. The Validation Forum (Ref. 5) endeavours to provide access to case building methods.

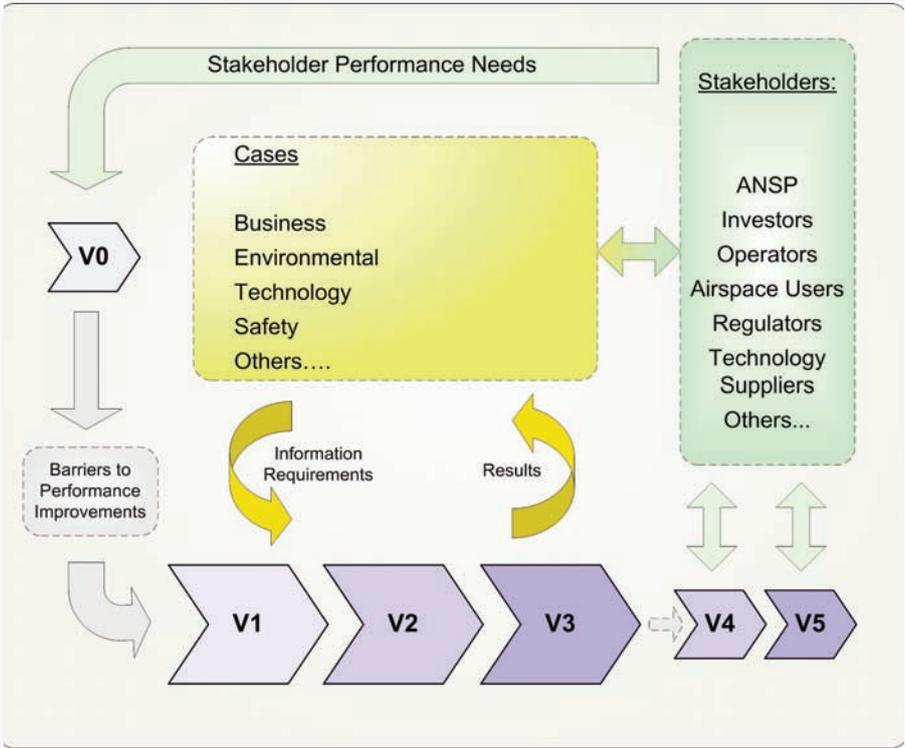


Figure 4: Studies supplying information to packaged results

3. Fitting the Parts Together

The three aspects described (Concept Lifecycle, Structured Planning and Case Based) fit together to form a process. This process is focused on developing a concept towards an application while demonstrating to key stakeholders how to achieve an end system that is fit for purpose.

The Concept Lifecycle is the central aspect of the validation process. The following sections describe how the parts of the process fit together along the lifecycle.

3.1 V0 Needs - Preparing for validation

The information from V0 on performance needs and constraints is considered as being generated away from the R&D environment and is continuously updated by teams involved in monitoring ATM performance. It is essential pre-requisite information that the validation process will need in order to show how a concept addresses both a performance need and circumvents known constraints.

The candidate concepts are also considered as being generated elsewhere. The validation process does not generate concepts it evaluates concepts.

3.2 V1 Scope

The validation process starts in V1 of the Concept Lifecycle.

The Structured Planning Framework is used to plan the activities of V1 which will examine what activities will be required in order to evaluate the concept as it develops towards an application.

The following steps are covered in V1:

- Step 0 State Concept and Assumptions (including problem description);
- Step 1 Set Validation Strategy (where evidence is needed to help to determine strategy move to steps

2, 3, 4 and 5);

- Steps 2, 3 and 4 may be used where exercises are needed to help determine a suitable strategy e.g. fast time modelling activities to help identify the scale of the problem in different airspace or airports;
- Step 5 will collect any evidence from the exercises that will be used as input to the validation strategy.

Cases

Supporting 'cases' will be created during this step. The cases will collect together stakeholder issues and will identify where evidence will be required to build the case – these needs for evidence will feed into the validation strategy.

3.3 V2 Feasibility

Chosen concepts move to V2 where development will continue to a state whereby operational feasibility should be established.

The Structured Planning Framework will be used to plan the validation exercises (continuously supporting the development activities).

The following steps are covered in V2:

- Step 0 State Concept and Assumptions (revisit previous work to ensure still valid),
- Step 1 Set Validation Strategy (revisit previous work to ensure stakeholder issues captured, strategy still valid re platform capabilities and high level objectives clear)
- Steps 2, 3 and 4. Repeated for every exercise undertaken in V2. These are the main focus of the activities to establish feasibility.
- Step 5 Information for dissemination. Should be considered at any time during V2 once exercises start to generate results.

Cases

Appropriate information will be channelled through the cases.

3. Fitting the Parts Together

Additionally demonstrations will be used for showing feasibility and convincing stakeholders of fitness for purpose.

3.4 V3 Integration

Feasible concepts move to V3 where integration takes place.

The Structured Planning Framework will be used to plan validation exercises.

The following steps are covered in V3:

- Step 0 State Concept and Assumptions (again revisit previous work to ensure still valid);
- Step 1 Set Validation Strategy (again revisit previous work to ensure stakeholder issues captured, strategy still valid re platform capabilities and high level

objectives clear)

- Steps 2, 3 and 4. Repeated for every exercise undertaken in V3.
- Step 5 Information for dissemination. Continuous during V3 once exercises start to generate results

Cases

These will be used to collect evidence about concept. If the concept appears to be successful these R&D cases will become the foundation for the cases in support of certification and implementation.

The following diagram (Fig 5) represents graphically how the parts fit together along the lifecycle. The emphasis of concept validation is on the R&D phases of V1, V2 and V3.



Figure 5: Lifecycle informing cases through structured planning

4. Key Validation Documents

The Structured Planning Framework described in section 2.2 and summarised in Figure 2 shows many outputs from the various Sub-Steps. Most of the described outputs are captured in three principle documents:

1. **Validation Strategy**, the output from Sub-Step 1.7 which captures most of the work performed during the Step 1 Set Validation Strategy;
2. **Validation Exercise Plan**, the output from Sub-Step 2.6 which captures most of the work performed in the earlier Sub-Steps of Step 2 Determine the Exercise Needs;
3. **Validation Report**, the output of Sub-Step 4.3 which captures the outputs of individual validation exercises.

The Validation Strategy will be created during stage V1 of the concept maturity model and should be updated as necessary depending on the results from the validation exercises and should be thoroughly reviewed at the beginning of phases V2 and again V3. A Validation Exercise Plan and a Validation Report should be created for each validation exercise that is conducted.

The Validation Report should be considered for entry into the library part of the Validation Data Repository. Specific information extracted from the report will be captured in the data repository part of the Validation Data Repository.

The recommendation of this methodology is that the Validation Strategy will be a living document setting the scene for the many potential exercises at the various phases of the lifecycle. This implies the need for an entity to manage its continuous development along that lifecycle.

5. Validation Information Storage and Dissemination

The availability of information from validation exercises and other forms of assessment is a key issue in validation. The E-OCVM considers two principle categories of validation information:

- *Unfiltered* information from any source in the form of reports and papers, not following a specific structure, but which appear to be relevant to ATM R&D i.e. a library;
- *Filtered* information that will be used to support the management of validation activities, i.e. a validation data repository.

The Validation Data Repository covers both library and validation data repository aspects. It is supplementary to E-OCVM. The remainder of this section is focused on explaining the principles behind the filtered part of the validation data repository.

The E-OCVM approach implies a structured framework for capturing and storing validation information, which if applied generally would promote mutual understanding and convergence of validation related information within the ATM R&D community. A common validation information framework serves two main purposes:

- Facilitate / ease the communication between currently ongoing ATM concept validation programmes / projects / domains;
- Involve various user groups / stakeholders in the validation process by providing them with easy access to consolidated, current validation data.

The management of information is therefore central to the efficient and effective application of the methodology. It is important that arrangements are made to ensure information is stored using a formal structure, a common format and standard across the contributing projects. The structure of the information storage should allow retrieval and analysis of process step outputs, for example:

- An overview of the high level validation objectives in terms of the concepts being developed, the scenarios being investigated and the benefit targets required. The overview should enable the structuring of the detailed validation objectives of the individual projects and the monitoring of how they are being achieved;
- A view of the past, current and planned project

validation work that enables the results from the activities to be seen in the context of the objectives and hypotheses set;

- A view of how the project validation activities are being performed, for example, validation tools, techniques, standard scenarios etc.

In this way information management is also a direct enabler of Step 5 (Disseminate Information to Stakeholders). It structures the validation information in a meaningful way for Stakeholder assessment and review both during project activities and at the end of the overall programme or Concept Lifecycle phase. It provides the means by which a project can present a picture of its contribution to the Concept Validation.

The scope and scale of validation information requires the assistance of automated database toolsets. The toolset that directly supports the structured information framework suggested by the methodology and provides a web-based means for dissemination of validation information is the Validation Data Repository (VDR) developed by EUROCONTROL for the ATM R&D Community. The VDR can be summarised as a “*centre for capturing, preserving and making available validation related data, including objectives, procedures, configurations, validation environments, exercise data, results and conclusions*”.

Full information about it can be obtained from the VDR web site at:

<http://www.eurocontrol.int/eatmp/vdr>.

6. Support to Validation

Users of this methodology who have questions or a need for explanations or further support should first visit the ValFor web site at:

<http://www.eurocontrol.int/valfor>

Various forms of support are available including:

- E-mail contact with EUROCONTROL validation staff;
- Guidance material to support the understanding and application of the E-OCVM;
- Useful web links;
- Useful documents;
- Various templates to support validation documentation.

Additionally the European Commission has launched projects to support application of the E-OCVM and other aspects of validation. Contact points to those projects can be found on the ValFor Web Site.

7. References

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PART II - VALIDATION METHODOLOGY: STRUCTURED PLANNING - STEPS 0 TO 5

Introduction to Part II

The Structured Planning Framework identifies 6 fundamental steps in a validation programme. Within each fundamental step there are a number of Sub-Steps (Figure 2 from Part I) which are intended as a framework to help the planning of validation activities.

Part II provides a more detailed description of the Sub-Steps. The outcome of these Sub-Steps is eventually evidence about the performance and behavioural capabilities of a proposed operational concept which can then be provided to key stakeholders. This information should demonstrate how known or expected barriers to improving performance will be addressed.

Part II does not provide guidance in experimental design, but is intended as support to identification of appropriate validation objectives based on an achievable validation strategy from which suitable exercises can be identified to provide necessary evidence.

The term 'exercise' is used to as a generic term to cover any activity that may be used to generate or present evidence to stakeholders.

Validation objectives are split into 3 levels – Programme, Project and Exercise (in descending order). These three levels of objectives cover many potential additional levels. The number of levels necessary depends on the difficulty of decomposing objectives from the top level performance targets down to experimental hypotheses. The grouping into three levels in this methodology is for the purposes of illustration, the actual structure of validation objectives will be closely linked to the structure of the programme.

This methodology assumes that development and validation of operational concepts are interwoven (interdependent) activities that can not easily be separated. It will sometimes be difficult and even irrelevant to differentiate if an activity is in support of development or validation. The term 'validation team' is used to cover those people actively involved in supporting the development and evaluation of an operational concept. The team is not considered as a fixed group of people exclusively working on validation.

Further support and guidance on the application of the various Sub-Steps can be found through the web site <http://www.eurocontrol.int/valfor>.

Description

The validation team cannot produce a good validation plan if it does not fully understand the exact nature of the problems the customer wants to either solve or circumvent. To enable this understanding it is useful to undertake a thorough analysis of the problem. The analysis should cover at least the following points:

- *Identify the Problem* – Broadly state the nature of the problem. This can be related to Key Performance Areas (KPA¹) e.g. safety, capacity limitations, controller/pilot workload. It should be stated whether the problem is one that already exists today or one that is foreseen in the future (perhaps in a given number of years, or by a set date) as this would determine the urgency of a solution. This description should also include information on the location of the problem (e.g. airspace specific, phase of flight specific) and time of the problem (e.g. peak hours, or time of bad weather).
- *Identify the Cause* – State where the problem lies. What part (or parts) of the ATM system contribute to the problem? If there is more than one cause identified, they should be ranked giving the main causes highest importance.
- *Stakeholders' Viewpoint* – Who is affected by this problem? (e.g. controllers, pilots) What are their opinions on the problem and how does it affect their operations?
- *Quantify the Problem* – It is useful at this stage to carry out an analysis that quantifies the problem since later in the validation activity the system's current or predicted performance will be used for benchmarking and for setting hypotheses. For example, delay analysis could be carried out where there is a delay problem. This will entail identifying performance indicators that will be used later as a basis for assessing the impact of the solution on the problem.
- *Constraints Analysis* – The problem will be bound by certain constraints, e.g. time, geographical location, environment or cost of solution. These constraints should be identified and listed. One major constraint is the time available to develop a solution. For example, if an urgent solution is required, it is not feasible to enter a development programme that may take several years to reach system / concept certification.

It is not necessarily the role of the validation team to perform all of the above analysis as the development team may have already carried out some of it. However, if any of the above has not been done it is the job of the validation team to ensure it is completed.

Understanding the problem, and thus the customers' needs, in this detail will enable the validation team to tailor an adequate Validation Strategy.

Inputs

- At present there is no common documentation structure for each project so this information will have to be gathered from various sources, usually under the supervision of the Programme Manager
- Work done by the Operational Concept team

Outputs

- ATM Problem Description

1: There is work in progress by the ICAO ATM Concept Panel (ATMCP) to define Key Performance Areas relevant to ATM

Description

It is the proposed solution - not the problem - that will be validated. Therefore, a thorough understanding of all aspects is required. As with the ATM problem, analysis should be carried out on the proposed solution. It should also be remembered that there may be more than one possible solution to the problem, or indeed more than one problem area and all should be assessed. The analysis should answer the following questions for each solution:

- *What is/are the proposed solution/s?* – Start with a general description of the proposed solution/s. Each solution will provoke changes to an operational procedure and these changes should be described in order to help determine the experimental set up. Where the full extent of changes is not known this is an indicator for more concept exploration to be undertaken before validation exercises can be structured.
- *What are the **expected benefits**?* – In what KPA will the proposed solution deliver benefits? Are all the KPA and problem causes given in the problem analysis addressed or will it only address parts of the problem? Will the proposed solution address all parts of the problem at once or will it be done in phases? If so the relationships between phases and benefits must be identified.
- *How does it intend to deliver the benefits (**benefits mechanism**)?* – In what way will the proposed solution resolve the ATM problem.
- *What are the **enablers**?* – Does the proposed solution rely on other existing systems or proposed developments? This is particularly important for advanced systems that tend to rely on anticipated improvements in technology.
- *Are there any **constraints**?* – Are there constraints imposed on the solution? e.g. introducing the concept must not increase controller workload. Many of these may come from the constraints given during the problem analysis. The validation process should check whether these constraints are met and judge their impact.
- *What are the **legal implications**?* – Are there any legal implications of the proposed solution? For example, will certification be required?
- *Are there any **assumptions**?* – What are the assumptions taken when designing the concept? e.g. the concept assumes sector throughput will not be greater than 40 aircraft per hour. The validation process should test these assumptions, the likelihood of them being met and the impact if the assumptions turn out to be false.
- *Are there any **limitations**?* – Are there any known limitations of the proposed solution e.g. will it only work in certain environments, or is it not optimal in bad weather?
- *Is it foreseen that it could create any new problems?* – Is it anticipated that the introduction of the concept could lead to new problems? If so – how will they be mitigated?
- *Where does the proposed solution fit into the ATM system or, in the case of a large programme of work, into the overall solution(s)?* – Where does this solution fit into the ATM flight cycle, working methods or procedures? If this solution is part of an overall solution, where does this solution fit in? How does it interact with other proposed solutions?
- *Are there any obvious areas that will require special attention in the validation process?* – Often in addressing the problem and solution it may become apparent that certain areas of the problem (or the way the solution addresses them) will require specific attention during the validation process. This should be identified and used in later stages of the methodology.
- *What are the **risks** associated with the development of the proposed solution?* – A final important analysis during this Sub-Step is a risk analysis. Any proposed solution will have an inherent risk associated to it in terms of current maturity, required level of development, required level of investment, impact on the baseline system, complexity of the solution etc. These development risks must be quantified and mitigated where possible.

The above list of questions is not exhaustive but it provides a basis for the type of questions that should be asked at this stage. As with the ATM Problem Analysis, it is useful if this work is documented using a common template of questions.

Alternatives Analysis

In order to demonstrate to stakeholders the added value of a new concept it is important to consider potential alternatives. There may be cheaper, easier to implement or more acceptable (to key stakeholders) alternatives that could make acceptance of the concept under validation very difficult. It is important that the positive and negative aspects of these various solutions can be compared.

N.B. This stage is a necessary pre-cursor to Validation work. It does not need to be repeated by the Validation team but is essential input to the validation work.

Inputs

- ATM Problem Analysis
 - As with the ATM problem, there is not generally a common document outlining the intended solution. However, information should be available from Programme managers.
 - Work done by Operational Concept team
-

Outputs

- Description of proposed Operational Concept or Operational Improvement(s), including their benefit mechanisms
- Typical operational scenarios
- Alternatives Analysis

STEP 1

Set Validation Strategy

Sub-Step 1.1

Identify the Stakeholders, their needs and involvement

Description

Stakeholders are the actors in the ATM system whose support, co-operation and advice are vital to ensure that the proposed operational concept can be brought into service. **The Stakeholders must be consulted throughout the validation process.** Stakeholder analysis is the identification of a project's key stakeholders, an assessment of their interests, and the ways in which those interests affect the project.

The first stage in the analysis is to identify the actual stakeholders. Anyone that has any input or is in any way affected by the implementation of the proposed concept can be considered a stakeholder. The size of the impact generally indicates the importance of the stakeholder.

Each group of stakeholders will have different concerns and objectives and therefore it is not enough simply to identify them. It is also necessary to understand the objectives and concerns of each separate group bearing in mind that often the objectives of one group will conflict with those of another group and a balance must be struck. There are various tools and techniques to support the process of consultation with multiple stakeholders and to rank their main concerns. Tools such as Analytical Hierarchical Processing can be useful in supporting this difficult aspect.

Another objective of this consultation is to identify what the exact information needs of the stakeholders are. It is important to identify the questions that the stakeholder is likely to ask during the validation process. This Sub-Step should identify those questions and what the form, content and detail of the required information should be. The validation process must provide this information.

Finally, the involvement of the stakeholder should be identified. This will identify when and how the stakeholder is to be involved and what form this involvement will take at each stage.

All information required should be obtained through a set of structured questions during consultations with the stakeholders. These questions should address at least the following:

- When are various stakeholders involved?
- What are their areas of expertise?
- What are their main concerns?
- How will the solution impact them?
- What involvement is required of them during the validation process?
- What resources are the stakeholders willing to commit (or avoid committing) to the project?
- What information does the stakeholder need in order to make their decisions and how is this information related to the problem/problem cause(s)?
- What does the stakeholder think is achievable in this stage in the process? How do they define what is achievable?
- What are their expectations of the validation process?
- How will they judge performance of the proposed solution?
- How will they judge performance of the validation process?
- Are there ongoing development activities by some stakeholders? Are they co-ordinated or conflicting?

The E-OCVM is based on an iterative, model-based approach to extracting and defining all the key ATM stakeholder needs. The idea is that the 'requirements' for a concept evolve over time to determine fitness-for-purpose as part of the validation process. Thus, initial validation activities should focus on identifying which of the candidate stakeholder needs the end-state concept will ultimately address.

In the early stages of concept development, the more basic term 'needs' is promoted to express a less stringent application than the term requirements. These needs that will be further developed into detailed concept requirements later in the process.

Each validation team should carry out their own initial stakeholder analysis at an early stage in the validation activity and continue this consultation throughout the later stages.

Each validation team should carry out their own initial stakeholder analysis at an early stage in the validation activity and continue this consultation throughout the later stages.

Inputs

- Information from the Programme Manager and previous similar validation exercises (for Stakeholder identification).
- Information on both operational problem and operational solution.

Outputs

- List of Stakeholders and their Needs
- Key Stakeholder questions that the validation strategy must address
- Initial Stakeholder Analysis (from first consultation), followed by regular subsequent consultations.

STEP 1

Set Validation Strategy

Sub-Step 1.2

Identify the Current and Target Levels of Maturity

Description

The purpose of this Sub-Step is to:

1. Identify what information already exists describing any previous evaluations of the concept under examination, this will include identifying any material available in libraries or perhaps structured in case based formats (e.g. safety case). ARDEP and the VDR library function are potential sources of information on relevant work (Ref 2);
2. Identify the current level of development of the concept and to state the level that the stakeholders expect the concept to mature to by the end of the validation process.

As the concept matures not only will the description of the concept become more detailed and comprehensive but the body of evidence that describes its behaviours and performances capabilities will grow as well (e.g. Safety case, Human Factors case, etc).

To help classify the stages in the concept development lifecycle, the FAA/EUROCONTROL Operational Concept Validation Strategy Document (OCVSD) (Ref. 3) identifies 6 main phases. Taking a concept from 'idea' to 'implementation' the concept will pass through 6 discrete levels of maturity, with each level having distinct criteria that must be met before a concept can be considered mature enough to progress to the next level. The 6 phases are:

- V0. ATM Needs** - As a prerequisite of concept validation, the ATM performance needs and barriers must be identified. To complete the validation of the concept, the concept must show that it can alleviate these barriers enough thus enhancing ATM performance to the anticipated required level.
- V1. Scope** - The phase where the concept should be described in sufficient detail to enable identification of the potential benefits mechanism (i.e. the change to operational procedures that will enable the known barrier to be alleviated). Some aspects of the concept will be unknown or unclear at this stage. They may exist as a number of options to be assessed during the further validation process.
- V2. Feasibility** - An iterative phase to develop and explore the concept until it can be considered operationally feasible. The main focus is on operability and operational acceptance. It is during this phase that operational procedures and requirements emerge. The number of iterations depends on the complexity of the concept and how often unexplained situations occur that need to be explained. At the end of this phase HMI, Operating procedures (for nominal and key non-nominal conditions) and phraseology should be thoroughly tested. This stage will establish the behaviours of the new system.
- V3. Integration** - The phase to integrate any required functionality into pre-industrial prototypes. Engineering processes can be explored to provide experience that will be useful to building the end-system. This phase is focused on integrating operating procedures by using realistic scenarios that are representative of what the concept must be able to manage in the target end-system. The focus is therefore on system level behaviour, performance and establishment of standards/regulations necessary to build and operate the required technical infrastructure. This work will enable costs and benefits to be clearly identified and provide information about the potential performance of the overall ATM system.
- V4. Pre-Operational** - Pre-operational preparation takes place during this phase. Pre-operational prototypes will be transformed into industrial products ready for implementation and all institutional issues concerned with procedures approval should be addressed (Out of direct scope for R&D).
- V5. Implementation** - This is the phase when products and procedures are combined to create an operational system at a specific site. Implementation is a complex and risky procedure and it can be expected that many pragmatic 'fixes' will be required to complete implementation successfully. (Out of direct scope for R&D).

Most programmes and projects are commissioned in order to develop one or more concepts from one level of maturity to another. This progression from one level to the next should be based around a clearly defined set of transition criteria. The transition criteria will come from the stakeholders and should be identified for each of the main stakeholder interest groups. As a minimum, transition criteria should be identified for a Safety case, a Human Factors case, a Business case and a Technology case.

If the transition criteria are met after the validation exercises have been carried out, then transition to the next level is possible. If the transition criteria are not met then the information gained from the validation activity is taken into account and another iteration of the concept development cycle is carried out for this level.

During the early stages of the concept lifecycle there are likely to be many short iterations of the development process given the rapid, dynamic development of the concept. This means that at lower levels of maturity, the time, cost and effort involved in the validation process is much lower. In later levels, as the concept becomes more mature and stable, iterations become fewer but the cost and duration of each is likely to grow.

Inputs

- Description of Proposed Concept
- Body of existing evidence from previous validation work
- Information from ARDEP and the VDR

Outputs

- Statement of current and target levels of maturity
- Set of Transition Criteria

Description

The use of the word 'expectations' is to help the E-OCVM user to understand that many different people will each have individual expectations about what a successful outcome could be.

Given the ATM problem, the stakeholders will have initial ideas of what they see as an acceptable outcome or 'final product'. These ideas form the basis of the validation expectations, which will in turn form the basis for the scope, direction and design of the validation activity. This information should be gathered during early stakeholder consultation.

When setting the validation expectations it is useful to ask the following questions:

- What are we *trying to achieve* in the validation process during each of the different phases of the concept lifecycle?
- What can we *realistically achieve* in the validation process during each of the different phases of the concept lifecycle?
- What do the *stakeholders expect* from the validation process during each of the different phases of the concept lifecycle?
- What would be an *acceptable validation product* at the end of each concept lifecycle phase?
- What is the *scope of the validation* at this stage in the concept's lifecycle?
- What *specifically will validation address*?
- What are the *transition requirements* for each of the relevant phases of the concept lifecycle?

The main issues that must be addressed by the Validation Strategy can be loosely structured into cases (e.g. safety, Human Factors, etc) at this point.

The guidance on the detailed structuring of cases is outside the scope of the E-OCVM², but further material can be found on the Validation Forum Web Site. However the information needs of the stakeholders must be addressed by the cases. The cases will have information requirements that should be addressed by the Validation Strategy.

At this point any case building activity must be activated in order to ensure case based information requirements are available for the next step of this methodology.

Inputs

- Statement of Current and Target Levels of Maturity
- Transition Criteria
- Stakeholders' Needs
- Key Stakeholder questions that the Validation Strategy must address

Outputs

- Validation Expectations
- Case Based Information requirements

STEP 1 Set Validation Strategy

Sub-Step 1.4 Identify Programme Validation Objectives and Key Performance Areas

Description

Depending on the structure of the Programme, there will be various 'levels' of validation objectives covering the breakdown of Stakeholders' Needs down to Experimental Hypothesis. **Programme Validation Objectives** are the top level validation objectives that cover the breakdown of Stakeholders' Needs to concept and performance specific validation objectives.

Case building will provide information requirements that will contribute to identifying the Validation Objectives.

The Programme Validation Objectives reflect the stakeholder needs and the validation expectations of the validation process at Programme level. They should cover broad topics such as scope of the validation, what should be achieved at each phase in the concept lifecycle, what can be achieved at each stage of the validation process, ATM Key Performance Areas (KPA) and technical issues.

These broad topics can be broken down into distinct and clear high level categories.

The objectives relating to the **ATM KPA** should relate to the selection of ATM performance areas that the stakeholders have identified as important. These also tie in with the strategic high level objectives in the ATM Strategy for the years 2000+ (Ref. 7) and generally refer to areas such as safety, capacity, workload or usability amongst others. It is likely that the KPA addressed will be the same as those highlighted in the descriptions of the proposed solutions. The proposed solution should have expected benefits and there should be benefits mechanisms highlighted that should provoke this change in performance. **A key aspect of the validation is to assess if the identified benefits are delivered as proposed. Assessment of the benefits and the benefits mechanisms will form the basis of many of the validation objectives.**

The objectives relating to the **scope of the validation** should relate to what specifically should be achieved by and during the validation process e.g. how the validation team intends to assess the concept; where they will place their emphasis; what validation is intended to bring to the concept development. The major input of this will be the validation expectations.

The objectives relating to the **Technical and Design issues** can relate to how the concept performs as a system or how mature the concept need be. They can include matters such as level of development, specific technical targets that must be met (such as implementation dates or functionality), or specific design issues such as the need to further develop certain aspects within the programme, such as a HMI or a specific platform.

Taking the above approach, it is possible that the objectives identified in this Sub-Step already represent more than one level of decomposition, whilst remaining at a Programme level. Later in the methodology the Programme Validation Objectives will be broken down further and allocated to Projects and/or Validation Exercises.

The document "An ATM Performance Measurement system" (found at Ref. 8) discusses an approach to determining ATM KPA (including examples).

STEP 1 Set Validation Strategy

Sub-Step 1.4 Identify Programme Validation Objectives and Key Performance Areas

Inputs

- Validation Expectations
 - Stakeholders' Needs
 - Key Stakeholder questions that the Validation Strategy must address
 - Case Based Information requirements
-

Outputs

- List of Programme Validation Objectives and Key Performance Areas

STEP 1 Set Validation Strategy

Sub-Step 1.5 Establish Initial Validation Requirements and draft Validation Strategy

Description

The purpose of this Sub-Step is to establish exactly what is required from the validation process as outlined in the Validation Expectations for each of the remaining phases of the concept lifecycle in order to address the Programme Validation Objectives. At a programme level it is often necessary to outline a set of projects to cover specific issues with a number of validation exercises to be included in each. This Sub-Step should provide enough information to ensure that the number and type of exercises chosen is appropriate.

The validation requirements will largely be driven by the descriptions of the proposed solutions, the validation expectations and the Programme Validation Objectives. They will therefore depend on such issues as:

- Performance indicators used to identify the problem
- Projects and validation exercises required, e.g. to fully cover scope, to achieve the required statistical relevance
- Programme Validation Objectives addressed
- ATM Scope of the modelling platform required
- Geographic scope of the platform (e.g. airspace)
- Realism required
- Fidelity of the platform and output data quality
- Resources required (staffing for Human in the Loop simulations, costs for computer based simulations etc)

These requirements should be gathered and detailed here. It is preferable to keep these requirements at a similar level to the level of the problem and solution descriptions. Enough information should be gathered to at least enable an initial estimate of the number of projects and validation exercises required with perhaps even enough information to choose candidate platforms. This information forms the basis of the draft validation strategy. Later the methodology will discuss the task of tailoring the draft strategy to fit the specific needs of the projects and concepts.

The draft validation strategy should try to avoid being constrained by resource and time issues. It will be a description of the most appropriate way to develop and validate the concept. The constraints of resource availability and time will be incorporated in Sub-Step 1.7.

Inputs

- Description of the ATM problem and proposed concept
- Validation Expectations
- Programme Validation Objectives

Outputs

- Initial Validation Requirements
- Draft Validation Strategy

STEP 1

Set Validation Strategy

Sub-Step 1.6

Selection of Validation Tool Type or Technique

Description

A tool or technique for the validation exercises needs to be chosen. The decision on which tool or technique to use will depend on:

- Initial Validation Requirements (Output of Sub-Step 1.5);
- Capability of platform(s) to support the selected concept and to deliver the quality of data required for evaluation;
- Platform availability.

The Initial Validation Requirements may suggest the need for more than one exercise and it may be beneficial (indeed it may be necessary) to use more than one tool or technique in these exercises. This may be because some tools or techniques are better suited than others to addressing certain aspects of the ATM system, thus helping to ensure better coverage of the validation expectations and objectives or it may be that the validation requirements change as the concept matures.

The first step is to compose a list of tools or techniques available for use, listing also their capabilities and limitations. They can then be compared against the validation requirements to see which of them meet the requirements. The most suitable tool(s) or technique(s) should then be chosen and subsequent validation strategies based around these choices.

Figure 5 shows an overview of the tools and techniques that will be considered in this methodology. It also shows some of the interactions between these techniques. Some methodologies can imply a rather one way interaction between various tools and techniques. In reality there is no set route to follow when using one or more techniques.

In each case it is up to the validation team to decide which tool or technique to use at what phase in the concept's development. Figure 5 illustrates that after any validation exercise, no matter what the tool or technique, there is a period of analysis or transition before the next exercise begins. In this way results from previous exercises are used as input for subsequent exercises. There should be no restrictions on which tool or technique is used after any other, as long as the requirements are met and the tool or technique is appropriate.

Inputs

- Programme Validation Objectives
- Initial Validation Requirements
- Draft Validation Strategy

Outputs

- Decision on tool type(s) or technique(s) to be used.

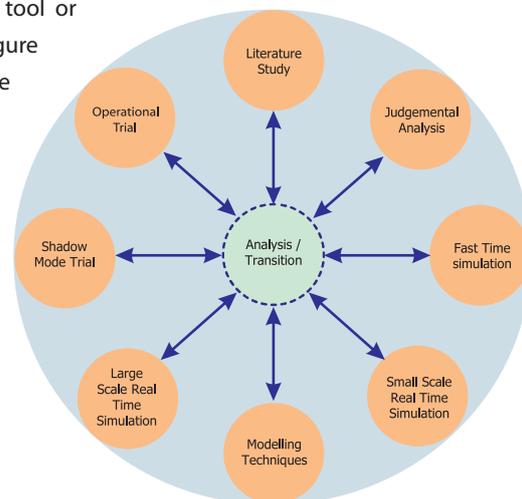


Figure 5: Interactions between tools and techniques

Description

This Sub-Step takes a summary of the work that has been done on gathering Validation Requirements and choosing tools and techniques and produces a statement of activities that the partners intend to carry out in order to validate the concept in each of the phases of the concept lifecycle.

The first purpose of this strategy is to outline the number and type of validation exercises required in order to meet the validation expectations.

The second purpose of the strategy is to outline the content of these validation exercises in terms of concepts, scope and validation objectives addressed. The choice of validation exercises should strategically address as many of the key Programme Validation Objectives as possible. The ranking of Stakeholder Needs in Sub-Step 1.1 and the associated risks are the background for the choice of which objectives should be addressed. This selection of validation exercises will be necessary to assess if the benefits expected by the stakeholders have in fact been delivered.

At this stage in the process the Validation Strategy need not detail individual project or exercise level objectives. It is more a statement of intent and a plan to show that the upcoming validation activity is well directed and is providing adequate coverage. In fact, due to the complex nature of experimentation, technology development and interactions between partners, many important decisions need to be highlighted and taken at this point in time, so that all stakeholders are aware of the issues at an early stage and action can be taken if necessary.

Enough detail should be provided by the concept descriptions in order to allow this high level scoping of the Validation Strategy with a more formal, detailed strategy being available later in the project.

In larger programmes there will be a need for many levels to the strategy. One may exist for the entire programme at a high level, with more detailed strategy descriptions for lower levels such as for individual projects. It is important that the different levels map onto the top level validation strategy.

Producing a Validation Strategy can be thought of as a two step process. Firstly a top down, idealistic approach taking into account:

- High level validation objectives (if applicable, shown per phase of the development cycle);
- Programme Validation Objectives (if applicable, shown per phase of the concept lifecycle);
- Interaction between validation activities of different projects or work packages in the programme;
- Interaction between validation activities of different concepts in the sub-projects or work packages;
- Expected benefits and other validation objectives;
- Outline of how the activities listed in this methodology interact with each other at project level.

The next step is to balance the idealistic approach against a realistic bottom up approach based on known limitations and constraints to the potential validation programme.

Finally a series of validation projects and potential exercises can be identified to constitute the Validation Strategy. This step should take into account:

- **A validation approach** – What sort of projects and validation exercises are needed in order to address each of the Programme Validation Objectives.

- **Validation schedule** – The remaining validation milestones need to be scheduled. There needs to be specific schedules for the projects and validation exercises planned.
- **Validation resources** – The Validation Expectations may be idealistic. At this point it is necessary to be realistic in planning given the time and resources available. The number and type of projects and validation exercises that can actually be planned will be constrained by budget, time, staff, technical limitations such as platform availability and even what exercises have been listed in original contracts such as Descriptions of Work or project proposals.
- **Selection of Projects and Validation Exercises** – Having taken into account the issues given above, a series of projects and/or validation exercises can be selected. Each project or validation exercises may cover a number of Programme Validation Objectives for one or more concept.
- **Limitations of projects and/or validation exercises** – For whatever reasons it may not be possible to address all Programme Validation Objectives at this stage (e.g. due to platform capabilities). Stating which objective the validation team cannot address is equally as important as stating those that they intend to address. The impact and implications of not being able to address these objectives will have to be kept in mind throughout validation planning. Alternatively, this may highlight the need for further work that was not originally in the project plan but is now needed in order to carry out essential validation activity.
- **Interactions between projects and validation exercises** – The list of projects and validation exercises has been built around the Programme Validation Objectives. It is also necessary to outline how the projects and validation exercises are built around each other. This might detail how a particular Programme Validation Objective is dealt with in more than one project or validation exercise or it may detail how the objectives/results of one project or validation exercise impact on another.
- **Who will carry out the Projects and Validation Exercises?** – Who has the capability to perform the projects and validation exercises outlined? When can they be carried out?
- **Do the projects and validation exercises address the Programme Validation Objectives?** – Continuing the building process towards an overall view, it is necessary to review the chosen strategy of objectives, projects and validation exercises to see if it addresses as many of the individual Programme Validation Objectives as possible and ultimately the validation expectations and stakeholders' needs. If it does not then the strategy will need revision.

This Sub-Step can be summarised as the point at which the realities of limitations and constraints to resources, tools and time need to be accounted for. Risk management techniques are useful at this point in identifying where to focus limited resources. The resulting choices form the basis of the Validation Strategy

Inputs

- ATM Problem Analysis
- Description of proposed solution
- Validation Expectations
- Programme Validation Objectives
- Choice of Techniques and Tools
- Resources and Time constraints

Outputs

- Validation Strategy

STEP 2 Determine the Exercise Needs

Sub-Step 2.1 Identify Stakeholder Acceptance Criteria and Performance Requirements

Description

In Sub-Step 1.2 this methodology introduced the idea of transition requirements for progression along the levels of maturity. These requirements and expectations should now be set and will come from the stakeholder information identified in Sub-Steps 1.1, 1.2 and 1.3.

Validation is about building confidence in an ATM system's ability to perform as well as the stakeholders expect. Acceptance Criteria and Performance Requirements are a set of benchmarks that will allow the stakeholders to build confidence in the system, decide if they should accept the concept and/or allow it to progress to the next phase in the concept lifecycle.

With the emphasis on the concept's performance, it is likely that these benchmarks will be based largely around the various Programme Validation Objectives, KPA and Areas of interest identified as being of importance to the stakeholders. For each area, the stakeholders will have expectations and thus, an idea of what they think will constitute acceptable performance. To capture these expectations and to ease the decisions during the review process, a set of Acceptance Criteria and Performance Criteria should be set early in the project. Meeting these 'targets' will be the main aim of the concept and the validation process will later set objectives to enable these areas to be assessed.

The first part of setting acceptance criteria is **Prioritisation and Rationalisation**. For this, the performance areas and areas of interest need to be prioritised taking into account relative importance, project objectives and practical constraints (such as time and cost). This process will ask some very pragmatic questions, for which it is better to get an answer early in the project. Examples of such questions are:

- What are the most important performance expectations to be met?
- What if these are not met?
- What if some are met, and others aren't?
- What if they are only partially met?

Since different stakeholders will have different interests, some assessment will need to be done to decide on the overall importance of each requirement. In some cases, weights can be added to particular stakeholders and their expectations to assist prioritisation.

To help further ease future decisions and clarify the criteria and requirements, the second part of this Sub-Step is the **Definition of Hypothesis**. The hypothesis will relate to the success of the operational concept in addressing the performance expectations with the required level of confidence. In the context of the validation exercise, a hypothesis is normally a proposition stating an expectation with a statement about the direction of performance e.g. safety must be increased; workload must be decreased. Such a hypothesis is typically drawn up for each objective, expected benefit or assumptions regarding the proposed concept and tested in an experiment. As well as the direction of expected change in performance it may be possible to hypothesise about the dimension of change. While it can be unrealistic to put an exact figure on these changes, guidelines can at least be set. These guidelines can be taken from the problem analysis (where the problem was quantified), the concept description (where expected benefits are detailed), stakeholder analysis, and forecasts (such as STATFOR Ref 9) and may, where possible, be put in terms of operational significance.

The output of this phase should thus be a ranked (in order of importance) list of Hypotheses, given for each KPA and with an expected (or desired) direction of change. The more Hypotheses that are found to be true (i.e. results are in favour of the expected benefit; expectations are met; direction of change is as required) then the more likely the concept is to be accepted.

STEP 2 Determine the Exercise Needs

Sub-Step 2.1 Identify Stakeholder Acceptance Criteria and Performance Requirements

Inputs

- ATM Problem Description
 - ATM Forecasts
 - Stakeholder Analysis
 - Validation Expectations
 - List of Programme Validation Objectives
-

Outputs

- List of Stakeholders' Acceptance Criteria and Performance Requirements.

STEP 2

Determine the Exercise Needs

Sub-Step 2.2

Identify Project and Exercise Validation Objectives

Description

At this stage in the validation process a Validation Strategy should exist in which individual projects and validation exercises have been chosen in order to address some part of the Programme Validation Objectives.

Project and Exercise Validation Objectives can now be derived based on the aspect of the Programme Validation Objective(s) being addressed in that particular project or Validation Exercise.

Each of these lower level objectives will address a certain aspect of the Programme Validation Objectives with respect to this particular project, exercise and/or concept. The Stakeholder Acceptance Criteria and Performance Requirements form a key input to this task.

It will be the objective of the projects and validation exercises to provide as many answers, meet as many of the Stakeholders' Needs and assess as many of the Programme Validation Objectives and KPA as possible. For each of these a lower level validation objective can be set. Given the level of detail and amount of information available at this time, it is possible to put together a series of detailed Project and Exercise Validation Objectives. Again, the Project and Exercise Validation Objectives may represent several levels of objectives depending on programme and project structure. Project Validation Objectives will address what will be covered in a particular project and Exercise Validation Objectives will usually refer to what can be addressed directly in one or more validation exercise

Given what is known about assessment capabilities and the validation exercises listed in the Validation Strategy, a list of these Exercise Validation Objectives can be composed for each of the validation exercises. Relating an objective to an exercise like this makes it much more specific, measurable, achievable, realistic and time-framed (SMART) objective.

Another purpose of detailing lower level objectives is that by listing the objectives in such a way it becomes easier to further break down the objectives into indicators and metrics (Sub-Step 2.4).

In Sub-Step 1.5 of this methodology, initial Validation Requirements were derived from the Programme Objectives and used to draft the Validation Strategy. As in that Sub-Step, the greater detail of the Project and Exercise Validation Objectives can be used to refine the initial validation requirements.

Inputs

- ATM Concept Descriptions
- Validation Strategy
- List of Programme Validation Objectives and Key Performance Areas
- Stakeholders' Acceptance Criteria and Performance Requirements

Outputs

- List of Project and Exercise Validation Objectives
- Refined Validation Requirements

STEP 2

Determine the Exercise Needs

Sub-Step 2.3

Refine Validation Strategy

Description

The Validation Strategy has been created in Sub-Step 1.7 Define Validation Strategy. The purpose of the Validation Strategy at the earlier stage is as a statement of intent and a plan to show that the upcoming validation activity is well directed and is providing adequate coverage. It also provided an idea of what would be required from the continuing validation process. When the strategy was first produced it was a high (programme) level strategy with Programme Validation Objectives and brief details on a series of projects and validation exercises. With a greater understanding of the concept (as should be gained by this stage in the validation process) and a refined set of validation objectives and requirements comes the need to revisit and refine the validation strategy.

At this stage the Validation Team should have reasonably stable descriptions of the following material:

- Descriptions of Proposed Concept
- Stakeholders' Needs
- Validation Expectations
- Programme Validation Objectives
- Project and Exercise Validation Objectives
- Stakeholders' Acceptance Criteria
- Refined Validation Requirements

In programmes and projects that are assessing more than one ATM concept there may be the need to combine concepts in projects and exercises. This choice of combination (or configuration) will need to be justified and explained in the strategy. Configurations may be chosen for interoperability reasons, reflections of how the concepts will be implemented over time or simply due to limitations on the number of exercises possible and thus the need to combine concepts. A concept description should be produced for each configuration during concept development and thus configuration choices will be made in coordination with the concept developers. Each description should contain the principles of operation for each concept or configuration and these will in turn be used as an input to the Validation Scenarios in later steps of this methodology.

The strategy should thus detail:

- Who will be carrying out the validation exercises
- Where they will take place
- When they will take place
- Choice of tools / techniques
- Choice of platform(s)
- Which objectives will be addressed in each project and exercise
- Additional projects and/or exercises foreseen to address certain key objectives
- Overview of any interactions, relationships or dependencies between planned projects and/or exercises

All this information together with the refined validation requirements will allow for a much more detailed validation strategy to be produced. Also because this sub-step is closer in time to planned project start or exercises means that planning can be revised with greater accuracy.

Inputs

- Descriptions of Proposed Concept
 - Validation Strategy
 - Refined Validation Requirements
 - Project and Exercise Validation Objectives
 - Case Based Information requirements
-

Outputs

- Refined Validation Strategy

STEP 2

Determine the Exercise Needs

Sub-Step 2.4

Identify Indicators and Metrics

Description

As described in Sub-Step 2.2 Validation Objectives should be specific and measurable. Thus a further breakdown of these objectives should identify the specific measures to be taken and the indicators and metrics that will be used to support measurement.

A metric is a system or standard of measurement; a criterion or set of criteria stated in quantifiable terms. An indicator is anything used in a scientific experiment to indicate quality or change.

A metric or set of them that can be used to achieve an indication of the concepts performance in relation to the KPA or areas of interest. Thus the top-down breakdown from validation expectations to metric is complete:

Validation Expectations → Programme Validation Objectives → Project Validation Objectives → Exercise Validation Objectives → Indicators → Metrics.

Given that this breakdown is likely to be quite complex, with several one-to-many relationships, it may be useful to produce a schematic showing the relationships between objectives, indicators and metrics. This can also be used to provide a bottom-up view of how each individual metric contributes to the overall objective or expectation.

Broadly speaking there are two categories of indicators and metrics.

- **'Generic' indicators and metrics** - these indicators and metrics are not concept specific. The focus is more on the ATM KPA than on the proposed concepts. Similar indicators and metrics can be applied to more than one concept and are particularly useful when comparing results across validation exercises or concepts. Common examples include R/T usage and sector throughput. Many lists of indicators and metrics currently exist in tools such as the VDR. These generic indicators and metrics often form the basis of complimentary assessments such as safety assessments and are particularly useful in later stages of concept maturity where the focus is on concept performance and 'repeatability' of results.
- **'Concept Specific' indicators and metrics** - these indicators and metrics relate specifically to the concept under investigation. They measure the usage of the tool, the way the concept works and the impact of the changes in the system following the introduction of the concept or tool. These indicators and metrics are designed for each concept so it is unlikely that they can be taken for other, different concepts. Examples of such concept specific indicators and metrics may be HMI based (e.g. the number of times a certain button on an interface is used) or procedure based (e.g. the number of times a controller delegates a task to the aircrew). In the early stages of a concepts development these indicators and metrics are particularly important in order to measure the acceptance and usefulness of the concept and the way it is used.

It is likely that the selection of the 'generic' indicators and metrics can take place before the selection of the concept specific ones and this can be done by using existing indicators and metrics chosen from documented sources. The concept specific indicators and metrics may not be fully chosen until very near the end of the validation preparation, up to the start of the exercises themselves. This is due in part to the continuing development of not only the concept but also the actual instantiation of the concept (perhaps in the form of a 'tool' on a platform) and also on the simulator capabilities.

Inputs

- Exercise Validation Objectives
 - Concept Descriptions
-

Outputs

- List of Indicators and Metrics.

Description

The purpose of this Sub-Step is to produce a specification for scenarios that will help evaluate the ATM concept in an operationally realistic manner. These scenarios should be targeted at the Exercise Validation Objectives.

Validation Scenarios are used to provoke ATM system performance and behaviour in a simulation setting, to test hypotheses and assumptions. Where scenarios have been used to describe a concept (to give contextual detail, to determine HMI needs and/or derive possible working procedures) those scenarios should be used as input to the definition of validation scenarios.

An operational concept scenario is a documented description of a sequence of events involving one or more 'actors' that is focused on some specific ATM function or procedure. This type of scenario is generally implemented during initial concept design and development phases. It allows various instances to be described during the identification and refinement of issues for further testing and development. An operational concept scenario applied in concept design can be used to describe various "what if" scenarios in order to judge or explain how a concept should work in these instances

A validation scenario is an extension of the operational concept scenario. It is a representation of the events, actors, and interactions of the operational scenario applied in a simulation environment. The objective is to address the performance and interactions described or expected in the operational concept scenarios. The simulation environment refers to various configurations of airspace, traffic sample, weather, failure modes, and any other controllable variables that might affect the performance of the ATM system. In this way, a validation scenario will test the assumptions in the concept scenarios and thus the concept design.

Validation scenarios are actually run in the validation exercises, therefore they will require specific traffic files, airspace files, and possibly scripted events in order to execute properly. They will also have associated validation objectives and be able to address specific indicators and metrics.

The validation scenarios will determine the platform requirements. Some scenarios chosen may highlight the need for very specific events, e.g. the safety and human factors cases could be a source of scenarios especially if non-nominal scenarios are required. The simulator must be able to cope with these scenario requirements in order to run the validation scenarios and test the associated objectives

In order to provide necessary functionality for the behaviours and indicators and metrics derived from the scenarios the chosen platform may need to be adapted (where feasible). The changes to platform capability are captured in the platform scenario requirements

Since adapting platforms can require a lot of effort it may be necessary to prioritise requirements in order that the most important ones are met. Given the lead time involved in taking platform requirements and implementing them and the show-stopping nature of not meeting some of these requirements this will require careful planning and control. The requirements may need to be updated regularly as the validation strategy is executed. This practice of adapting platforms to validation needs is better than defining validation according to simulator capabilities. It ensures a more complete coverage, ensures that required information can be captured and promotes advancement in validation capability.

This step is carried out in six steps, as follows:

- Determine Scenario Aims
- Determine Scenario Characteristics
- Design Scenarios
- Confirm scenarios with client/stakeholders
- Produce Traffic Samples and simulation files
- Produce Platform Scenario Requirements

The appendices of the OCVSD (Ref. 3) summarise the results of common US/EUROCONTROL practitioner workshops on Validation Scenarios.

Inputs

- Operational Concept typical scenarios
- Description of the ATM Problem and the ATM concept
- Exercise Validation objectives
- Indicators and Metrics
- Current simulation platform capabilities

Outputs

- Validation Scenario specification
- Traffic samples (if required)
- Platform Scenario Requirements

STEP 2

Determine the Exercise Needs

Sub-Step 2.6

Produce the Validation Exercise Plan

Description

This Sub-Step is a further extension of the Refined Validation Strategy (Sub-Step 2.3) but this time it will focus on the planning and specification of an **individual validation exercise**. For each validation exercise listed in the Validation Strategy a plan should be produced formalising what is said about that exercise in the Strategy, ensuring that all parties are aware of the timing and scope of the activities in the validation exercise and to start developing a formal trial design. The output from this Sub-Step will be a Validation Exercise Plan.

The Validation Exercise Plan usually has 3 main elements:

- Exercise Scope and Planning
- Analysis Specification
- Detailed Exercise Design

Since this is a key document in the validation planning it is likely to have a wide audience. Therefore some recipients may not have been fully involved in the project before this point and it can be useful to include introductory paragraphs on the project and its aims and objectives.

As with all plans this document is liable to change as the validation process continues, especially given that this Sub-Step may overlap with the activities on the Refined Validation Strategy and the Scenario Specifications.

Exercise Scope and Planning

The Exercise Scope and Planning details the exercise specific information concerning; fit with the Refined Validation Strategy addressed; Exercise Scope; and Exercise Planning and Management.

The sections of the document discussing the fit with the **Refined Validation Strategy** and rationale for the exercise should contain information on:

- Stakeholders and their Acceptance Criteria
- Exercise Validation objectives and KPA
- Choice of Indicators and Metrics
- Overview of any interactions, relationships or dependencies between this and other planned projects or validation exercises

The sections detailing the **scope** of the exercise should contain information on:

- Description of ATM problem and concept (and configurations used)
- Tool(s), Technique(s) and, where appropriate, platform(s)
- Airspace used
- Organisations chosen
- Likely length of the Validation Exercise (and thus an indication of the likely number of exercises runs based on resources)
- Validation Scenarios

Finally, the practical details of exercise **planning and management** should be given, including information on:

- Resources:
- The activities to be undertaken
- When the activities will be performed
- How the activities are to be undertaken (regarding possible actors and technical personnel in the background)

- Responsibilities in the exercise
- Risk

Analysis Specification

The aim of the Analysis Specification is to state:

- Training requirements
- Data collection methods
- Analysis methods
- Statistical hypothesis
- Operational and Statistical significance
- Outline reporting plans

A plan is required for each exercise to support the planning and execution of the measured runs. It draws together all the relevant information on the conduct of the measured runs and the subsequent **analysis of the results**. In this way any gaps or inconsistencies in these aspects of the validation exercise can be identified and addressed.

The **measurements** section of the plan will describe the measurements to be used to assess each Exercise Validation Objective or area of interest. At this stage, the final decisions should be taken about which measurements will be taken during the exercises. A number of measurements could contribute to more than one objective. The Exercise Validation Objectives, identified in Sub-Step 2.2 should be stated under the heading of the related Programme and/or Project Validation Objective. The hypotheses should also be noted along with a description of the measurements that are to be recorded.

Likely **operational and statistical significance** levels should be stated here, with an explanation of the reasons why these levels were chosen.

When controllers are involved (e.g. in real time simulations) the analysis specification should consider the requirements placed on controllers (e.g. sector validity) and the need for in-depth training before the simulation.

When conducting shadow mode trials the analysis will have to consider the level of impact the new system or concept actually has on the data being collected. In 'passive' shadow mode it can be hard to attribute effects of the system on the actual traffic.

During Step 1 the Stakeholders' Needs and questions will have been identified. These will drive the **format of the analysis reports** produced and this format should be stated here. The use of tools such as the VDR (Ref. 2) for reporting should also be considered.

Without being able to collect the required indicators and metrics, the analysis can only take place on a qualitative level. Therefore the analysis methods, indicators and metrics outlined in the Analysis Specification will have **analysis requirements**. The analysis requirements should enable the capture of all the required indicators and metrics. They may also highlight the need for additional analysis tools or data processing tools to be set up to shorten the analysis time after the simulation. It is important that gaps in the testing are kept to a minimum as doubts may remain about untested areas. If there are measures that cannot be taken or parts of the system (ATM problem area or concept) that cannot be tested then this needs to be highlighted.

One of the more common requirements is on the format and content of data recorded by the simulator platform. It is common for the validation team to provide the platform team with a list of **datalogging requirements** in the form of the details and definitions of all the parameters expected to be logged by the simulator and a common format for their log messages. By doing this the validation team can ensure the correct data is logged in a format of their choice. This commonality helps when it comes to compilation and analysis of the logs.

Detailed Exercise Design

The aim of the detailed exercise design is to provide a structure for the specification of the exercise runs, to ensure that the results from the runs provide suitable data to enable the analysis to be carried out and thus to provide robust evidence to confirm or deny the hypotheses developed for the validation exercise.

The method used for detailed exercise design will vary according to the type of exercise, analysis technique to be used and the resources available, including the capability of the validation platform, the availability of experienced participants, financial resources and available time.

The design should include information on the following:

- For judgemental techniques, the specifications will consist of the list of experts to be consulted, and the questions and concepts to be discussed.
- For real time and fast time simulations:
 - ◆ A statement of the length of the simulation;
 - ◆ A statement of the number of exercises to be executed (measured and training) in the simulation;
 - ◆ A description of the factors being experimented;
 - ◆ A description of the scenarios to be used during the exercise;
 - ◆ A timetable for the planned exercise.
- For shadow mode and operational techniques, the specifications will be for timetable and nominated operational staff and, for example, if aircraft are the focus of the particular validation, flight plans.

This methodology is not intended as a guide to experimental design. That is covered by many other tried and tested methods.

Inputs

- Refined Validation Strategy
 - Exercise Validation Objectives
 - Indicators and Metrics
 - Validation Scenario Specification (in parallel, this is likely to be a two-way interaction)
-

Output

- Set of Analysis Requirements (including Datalogging Requirements)
- Validation Exercise Plan, including Analysis Specification and detailed design

STEP 2 Determine the Exercise Needs

Sub-Step 2.7 Prepare the Platform or Facility

Description

Although this appears as the penultimate Sub-Step in this step, in reality it is likely to be run in parallel with Sub-Steps 2.5 and 2.6.

This Sub-Step involves reviewing all the various plans and requirements that have been identified so far and putting them into place on the validation platform or facility. The requirements include:

- (Initial) Validation Requirements
- Platform Scenario Specification
- Traffic Samples and simulation files
- Analysis Requirements
- Datalogging Requirements

The aim of preparing the platform is to configure it to represent the ATM problem and the operational concept as expressed through the scenarios. The elements of the platform or facility that need to be considered are shown in Figure 6.

The core of the platform consists of the platform or facility itself, but it cannot be considered in isolation from the input files, and the requirements of data analysis.

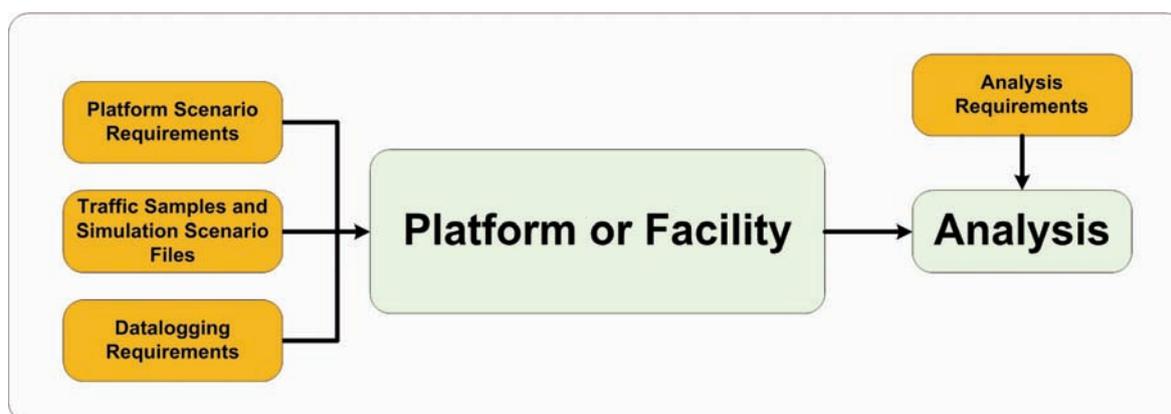


Figure 6: Core Elements of the Platform or Facility Preparation

These elements are now considered:

- The tailored preparation of the simulator will be driven by the scope of required modelling and the Platform Scenario Requirements derived in Sub-Step 2.5. The platform or facility must be able to meet all the requirements laid out in these activities.
- A set of Traffic Sample and Scenario files will be derived from the scenario specification (Sub-Step 2.5). Typically this may include traffic sample files, airspace structure files or ground layout plans, and scenario events or script
- As analysis requirements have been stated, these need to be considered in the light of currently available analysis tools, as time may be needed to develop or acquire new tools. The customer may have particular requirements, and the way in which results are to be presented may be influential too.

STEP 2

Determine the Exercise Needs

Sub-Step 2.7

Prepare the Platform or Facility

- Preparations need to be made for the measurements and for collecting feedback from the exercise participants. This may comprise the implementation of datalogging requirements for data collected directly by the platform. It may also include the set-up of measuring equipment like ISA boxes and the development of questionnaires. Observations are recorded by Subject Matter Experts (SME) during the measured runs, and the validation staff, who will be acting as observers and SME, will need to be trained.

As far as the development of software is concerned, it should follow established software development practices and be subject to Quality Management.

Inputs

- Unconfigured Platform
- Platform Scenario Requirements
- Validation Scenario Specification
- Traffic Samples and Input Files
- Analysis Requirements
- Datalogging Requirements
- Validation Exercise Plan

Outputs

- Prepared and configured validation platform or facility

Description

The description of this Sub-Step will use fast-time and real-time techniques to illustrate the work that can be expected during this sub-step.

Fast-time techniques

Once the platform has been prepared, it must be tested and its suitability to support the validation exercise demonstrated, so that it is acceptable to all parties, including the customer. Some iterative development may be necessary. This process familiarises the customer with the simulation platform and builds confidence in its capability. A visual representation of the simulation may be very powerful at this stage.

The fidelity of the simulation depends upon the extent to which it represents the ATM system to be validated, and its real world context. To an extent this is subjective, but any tools that allow controllers to assess whether or not the correct procedures are being modelled should be used at this stage. This may result in suggested changes to simulation parameters (e.g. arrival separation) or to the underlying behaviour of the simulator. It is also possible that additional analyses, not specified in the original validation plan, are seen to be useful.

This step is only complete when all parties can accept the fast-time model developed.

Real-time techniques

The real-time platform is tested through a shakedown trial. This is a trial of typically one week that may involve the use of operational participants. There will be no plans to make any measurements for analysis but the data logging, collection and analysis process can be tested.

The objectives of the shakedown trial are to make sure that the platform satisfies the following criteria:

- Forms a representative model of the aspect of the real world that is important to the specific exercise (i.e. the model should be validated)
- Provides a robust and reliable platform for measurements. Recently developed software can be unstable and liable to fail
- Flaws / potential pitfalls are kept to a minimum. When measuring equipment is used it needs to be calibrated. Questionnaires need to be reviewed.

Exercise participants need to be trained since they are usually not acquainted with the new procedures and/or supporting tools. They may need to develop a different working method.

By using specific training runs, the participants are focused on the differences compared to the situation they are used to. In this way the learning effect during the measured runs is minimised.

Only after acceptance by the customer and the training of the participants can the execution of the validation exercise begin.

As far as software is concerned, the testing/verification should follow established software development practices and be subject to Quality Management.

STEP 2

Determine the Exercise Needs

Sub-Step 2.8

Conduct Pre-exercise Testing and Training

Inputs

- Platform configured to represent the scenario (including the ATM Concept)
-

Output

- Tested validation platform ready for the validation exercise runs to be performed
- Trained participants (where required)

STEP 3

Conduct the Exercise

Sub-Step 3.1

Conduct the Validation Exercise

Description

The purpose of this Sub-Step is to execute the validation exercise on the validation platform in order to obtain a set of measurements, user feedback and other data that will be analysed in Step 4. This should be done according to the description in the Validation Exercise Plan.

At the end of Step 2, everything has been left ready to perform the individual validation exercise run(s). No generic guidelines can be given in this regard that would be applicable to all validation techniques, so that this section will simply provide general information and guidelines.

First, information will be provided regarding the different types of data that may be collected during the run(s), because the type of data determines the type of analysis that can be performed in Step 4. In addition, a brief overview of data collection methods will be given.

Second, a brief series of guidelines for conducting the validation exercise will be provided for each of the four overall types of validation techniques.

Data Collection Methods

This section provides an overview of data types and data collection methods.

The following data types are, in general, applicable to ATM validation exercises (and simulations in particular):

- Qualitative/quantitative.
- Objective/subjective.
- Intrusive/non-intrusive.
- Binary/not binary.
- Nominal/ordinal/interval/ratio-level.

Data can be collected during validation exercise runs by either automated means, humans (the participants in the exercise or the validation team), or some combination of both. Data collection methods can be broken down into the following generic categories, illustrated in Figure 7 below:

- Data recorded by the automated/simulated system
- Data gathered through observation of the exercise (employing observers during simulations is particularly useful for spotting behaviour that the system cannot pick up)
- Physical data measurements from the participants in the exercise.
- Data and/or opinions provided by the participants

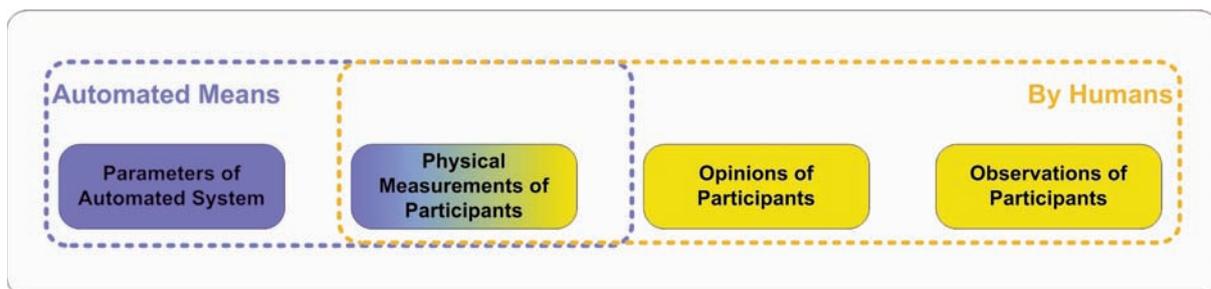


Figure 7: Data Collection Methods

Guidelines for Executing Validation Exercises

This section provides general guidelines for executing exercises using some of the main types of validation techniques. As has been stated above, no detailed guidelines can be provided for execution of validation exercises because of the enormous variation between techniques as applied to individual exercise runs.

Literature Study

The performance of a literature study will involve reading all or parts of the documents identified and making structured notes based on the analysis plans.

Executive summaries of the selected documents will provide a background for the information obtained from the documents. This will set the context for individuals who have not read the document, and can provide important information for the performer of the validation exercise as well. This allows the analyst to weigh data obtained from the different documents describing validation exercises with similar aims and scope. It is also important to record any assumptions either in the documents surveyed or by the exercise performer.

The output data from the literature study are a list of qualitative statements, and possibly numerical results, from relevant documents providing the "evidence material" for testing the hypotheses.

Judgemental Techniques

In judgemental techniques, Steps 3 and 4 are frequently part of an iterative process, that is, the output of one step is used as input for the other.

The exercise runs will involve eliciting and recording the opinions from a representative group of experts; the opinions will be recorded in accordance with the plans. This may be in the form of a meeting, at which the validation team facilitates the discussions or it could be purely paper based, circulating specific information and questionnaires e.g. by mail or e-mail to the experts. The results may then be collated and analysed and used to support further discussion or the review of conclusions.

The output data consist of a set of recordings of subjective views. These will normally be text based, but may be supported by video and audio recording

Fast-Time Techniques

Before the execution of the validation exercise starts, the validation team will have a clear plan in place. This will provide a detailed specification of the configuration of the fast time tool and the inputs representing the scenario.

Execution of a fast-time validation exercise runs therefore comprises executing the process or running the tool for each planned scenario. In order to avoid bias in the results, each scenario should be run with random variations a multiple number of times (10-20 is typical) with traffic representative of the validation scenario. This avoids one particular ordering of the traffic sample having too great an effect. Detailed advice cannot be provided for this Sub-Step, as it will be very dependent on the particular platform being used.

Batch scripts can be created to allow the fast-time simulator to run with little or no operator intervention. Simulations can therefore be run overnight or during the weekend.

The "raw" results from a fast-time validation exercise could range from a small list of calculated data from a spreadsheet to large data sets of measured data. The data are numerical and objective.

Real-Time Techniques

When the application of a real-time technique reaches Step 3, a detailed Exercise Design will be available setting out the precise configuration for each measured run. There will also be planned sessions for debriefing and for visitors. The planning phase should also have identified the actions to be taken in case of equipment failure.

Each exercise goes through a similar process. It starts with briefing, to give the participants an idea of what to expect from the exercise runs and to know what they are expected to do. When this is complete, the measured runs start and the data is collected. The data collected may include logs recorded digitally, notes from observers, recordings from videos, and questionnaires completed after the measured run finishes. Periodically there should be debriefing sessions to collect feedback from the (measured) participants.

There may also be data provided through the visits of invited expert stakeholders whose views on the operation of the operational concept also need to be recorded. In such cases it should be noted that controllers should be kept isolated from visitors, observers and stakeholders in order to avoid any interference in their work.

The "raw" results of a real-time validation exercise are varied. There will be different types of data:

- Objective measured data obtained from:
 - A prototype implementation of the operational concept;
 - the ATM data processing system;
 - monitoring equipment, e.g. eye movement tracking, heart rate monitor.
- Subjective measured data (e.g. from the ISA panel and the records from the exercise observers, video recordings);
- Subjective opinions of the participants recorded in questionnaires and gathered in the debriefing sessions.

The OCVSD (Ref: 3), Appendix 1 provides best practices for Human in the Loop (HITL) experiments.

Inputs

- Validation Exercise Plan
- Validation Scenarios
- Configured and tested Validation Platform
- Trained Participants (where required)

Output

- Raw Data (in a form suitable for analysis)

STEP 3

Conduct the Exercise

Sub-Step 3.2

Assess Unexpected Results or Behaviours

Description

So far, the validation activity should have been very well mapped out with numerous results, if not expected, then at least anticipated. However, often during an exercise, unexpected results or behaviours occur. It is vitally important that the validation team detect these unexpected results or behaviours and analyse why they have occurred. Such unexpected situations maybe of vital importance to further development and should not be ignored or considered as a nuisance.

Any unexpected results shall be assessed before the main bulk of the analysis, because of the unknown impact they may have, and also to give the opportunity to further investigate these during the exercise. Once the impact of any unexpected results has been fully analysed, decisions can be taken together with any involved stakeholder as to whether any modifications to the validation strategy or the validation analysis are necessary. If so, the applicable Steps/ Sub-Steps need being repeated.

Compiling problem reports is useful at this stage to help others interpret the seriousness of the unexpected results or behaviours. Different reports can be compiled for different people including:

- Concept Designers – reports on unexpected behaviours in ATM system as result of the introduced concept; unexpected controller behaviours or working procedures
- Analysis Team – reports on specific unexpected results or behaviours detailing when they occurred and possible impact. This can act as a ‘forewarning’ to the analysts and allow them to be prepared for unexpected results in the analysis
- System Engineers – reports on specific platform issues.

Inputs

- Validation Exercise

Output

- Assessment of Unexpected Results and / or Problem Reports
- If necessary: Ad hoc re-planning to be considered later in reiteration of certain activities

STEP 4

Determine the Results

Sub-Step 4.1

Perform the Analysis Specified in the Analysis Specification

Description

The purpose of this Sub-Step is to perform the methods of analysis as specified in the Analysis Specification (and incorporating findings of Sub-Step 3.2 if necessary) on the measurements generated in Step 3, in preparation for the production of the analysis contributions in Sub-Step 4.2.

Whatever the validation technique used, the analysis techniques available can be divided into different categories that can be applied to different types of data:

- **Qualitative Analysis:** Qualitative techniques aim to extract the meaning and conclusions from a set of non-numerical data, but without necessarily giving a specific numerical result. These techniques look at the ranking of factors or opinions, and the overall characteristics of the data, rather than the specific values. The techniques may involve ranking answers to questions, investigating the similarity between responses, following a line of logical reasoning and conducting a content analysis on a set of subjective responses. It is possible to generate numerical data, such as counts, through qualitative analysis and then subject this to quantitative analysis.
- **Quantitative Analysis:** Quantitative techniques intend to reach a specific numerical result, often with an associated statistical level of confidence. There are many quantitative statistical tests, and an attempt will not be made here to describe them all or to state which are most accurate. Further detail can be found in many statistics books (e.g. [Statistic for Management] and references therein). The quantitative analysis can be sub-divided into descriptive and inferential techniques:
 - Descriptive techniques are concerned with making concise and intuitive descriptions of the data to aid interpretation, such as by making graphs and histograms;
 - Inferential techniques aim to derive a general result from a limited set of measurements and then testing hypotheses. This leads to statements such as "with 95% confidence, the number of flights per day from a specific runway can be increased by more than 5% by implementing a new procedure".

Inferential techniques fall into two types, parametric and non-parametric: Parametric analysis techniques assume some distribution of results, while non-parametric studies suppose no assumptions on underlying distribution of data. Hence the latter are less powerful.

When the descriptive and inferential statistics have been performed, and any qualitative analysis on the subjective data has been done, the generality of the results along with any assumptions and constraints on the exercise data needs to be considered. Also the statistical significance needs to be calculated for all results where possible, and be reported together with the results.

Careful use of appropriate techniques, including a clear view of the assumptions made, will enable the most value to be obtained from the data. Some dangers are:

- **Implicit assumptions:** Some analysis techniques will assume the nature of the distribution from which the data is chosen (in particular, they may assume a Gaussian probability distribution), and if such assumptions are not true, the analysis may be fundamentally flawed.
- **Inappropriate generalisation:** Any analysis will only be as reliable as the data used. Though the analysis should aim to generalise the specific results to a wider context, this should only be done when there is sufficient volume and variety of independent data.
- **Over-reliance on statistical significance:** Statistical significance is only related to the number of measurements and error model. The overall confidence should take into account the validation exercise fidelity and non-independent measurements and equipment inaccuracies.

STEP 4

Determine the Results

Sub-Step 4.1

Perform the Analysis Specified in the Analysis Specification

- **Misleading presentation:** Descriptive statistics can easily be misinterpreted. Non-linear, broken, or non-zeroed axes should only be used where strictly necessary. Error or confidence bars should be added where possible, such that it is clear to the reader where data is sparse and inconclusive.
- **Not accepting the “wrong” result:** Analysis may show the system to have a negative impact. Stating that the system has a negative impact is as valid as stating where a system has a positive impact.
- **Inadequate understanding of Human factors related issues,** e.g. insufficient training, learning curves, multicultural issues, attitude of participants towards the proposed problem solution.

The relevance of these analytical techniques for each of the four main types of validation techniques is as follows:

Literature Studies

The literature study provides only qualitative data for analysis. The data must therefore be analysed using qualitative techniques. The analysis will typically start with ordering the list of documents by importance, which means by relevance of the conclusions/results in that document with regard to the present validation exercise. Relevance depends on the scope of the reference document, the subject studied and the approach used. Generally the more similarity between the reference document and the own validation exercise, the more relevant it is. It is however up to the experience of the exercise performer to judge this.

The documents with highest relevance will determine whether a hypothesis is accepted or rejected. The less relevant documents affect the level of confidence in the hypothesis. In particular, when there are significant differences between higher and lower importance sources, the level of confidence in the trend identified will be lower than when they all point in the same direction.

Judgemental Techniques

Judgemental techniques initially only generate qualitative data for analysis. Qualitative techniques must therefore be applied to draw together views and synthesise intermediate conclusions. A key element of the analysis with judgemental techniques is its close feedback with the previous step where the data is gathered. The qualitative techniques applied at this stage therefore need to be efficient so those summaries can be produced quickly.

Fast-time Techniques

At this stage in the exercise, the analyst should follow the detailed Analysis Specification that was produced in the second step. The types of analysis that are feasible will have been determined by the original exercise design that has been selected for the measured runs.

Some general steps need to be followed:

- *Check the data* – The first thing to do after a calculation/simulation run has been executed is to check if it has run correctly. Some output files may have been corrupted for some reason, or an incorrect input parameter may have been used, despite verification of the input files. If this is the case, the cause must be traced and corrected. After that the specific calculation/simulation run will be repeated.
- *Perform the analysis* – The data collected in a fast-time exercise is numerical and therefore amenable to quantitative statistical techniques and the use of statistical measures and hypothesis testing should be considered.
- *Consider assumptions* – The quality of the assumptions in the modelling should be considered as part of the analysis. This is particularly important with fast-time validation exercises because there are no human actors involved who can provide immediate feedback whether the simulation is realistic or not. Also the affect of any limitations imposed by the platform in the scenarios or operational concept modelled need to be considered.

Real-time Techniques

The analysis of data obtained using real-time techniques is very similar to the analysis of data from fast-time techniques described in the preceding sub-section, although the type and amount of data may be different. Therefore other analysis techniques may be required. For example the subjective data can be used to support the quantitative analysis conducted on the numerical measurements.

Some specific issues related to real-time techniques are:

- Unusable measurements that may be the result of:
 - Inaccurate measuring equipment;
 - Equipment faults or technical problems;
 - Incorrect input files/parameters;
 - Insufficient training;
 - Poorly controlled conditions.
 - Since ATM actors are involved, the amount of subjective data relative to objective data is probably higher. Moreover, since these subjective data are usually from a small number of individuals, it should be considered whether they represent the views of the whole ATM community
-

Inputs

- Raw Data collected in Step 3
 - Analysis Specification
-

Outputs

- Analysed Data

Description

The results generated in Sub-Step 4.1 can be compared to the original Stakeholders' Acceptance Criteria and Performance Requirements set out in Sub-Step 2.1. This enables the validation team to see which hypothesis has been met and also understand the operational significance of the results. Often a result may be determined as being statistically significant but still may not be considered as operationally significant when viewed against the operational context and the inverse may also happen. This comparison between significance of measured results and operational opinions about the significance will impact which of the results could be considered as meaningful. Conflicts between observed results and operational opinions must be addressed at this stage to help determine how the results should reflect any contradictions.

A set of analysis contributions can be made for each of the KPA (or Project Level Validation Objectives). Each analysis contribution contains all meaningful results (both quantitative and qualitative) relating to that particular KPA. These contributions should be fully traceable and auditable. The schematic of objectives, metrics and indicators produced in Sub-Step 2.4 can act as a basis for this. In order to assist further, the contributions can be stored in a data repository such as the VDR (Ref. 2)

At this stage it is not the role of the validation team to draw conclusions about the success or failure of the operational concept. They shall objectively state the results and determine how these results relate to the original criteria set at the beginning of the validation activity.

Inputs

- Stakeholders' Acceptance Criteria and Performance Requirements from Sub-Step 2.1
- Indicators and Metrics (schematic) from Sub-Step 2.4
- Results from Sub-Step 4.1

Outputs

- Analysis contributions

STEP 4

Determine the Results

Sub-Step 4.3

Prepare and Review Validation Report

Description

The validation report is the main output of the validation activity and shall contain a synthesis of the results from all the completed exercises.

The validation report should contain information on:

- Review and Introduction
 - Programme/Project Background
 - Programme Validation Objectives
 - Project Validation Objectives
 - Exercise Validation objectives
 - Review of exercise
 - Analysis methodology
 - Any problems encountered in the validation activity
- Results and Discussions
 - Generally only high level meaningful results in direct relation to the Stakeholders' Needs
- Review of results
 - As in the analysis contributions, results should be related back to the original criteria and placed in operational context

As most reports are aimed at higher management the report should provide an overview and highlight only the key results in their operational context. It should not be too technical. Those wishing to find out more details of the analysis can be referred to the analysis contributions.

There are a number of key points to consider when composing a report:

- *Aim of the document* – the aim of the validation report is to summarise the validation activity and to objectively present the key findings. It is not meant to state conclusions about whether or not a concept is worth pursuing.
- *Target Audience* – A distribution list of the target audience should be drawn up before work commences on the report. This list will typically involve the major stakeholders and management. Attention should be paid to the sensitivity of the information and restricted distribution may be necessary. The target audience will determine the level of detail. A report to management will not require as much detail or technical content. However, this should always be made easily available to interested parties.
- *Scope* – The report is concerned with this particular phase in the concepts development. Past phases can be referred to in order to gauge progression and development. Recommendations for future validation work can also be outlined.
- *Key information* – It is not necessary to include all the results generated. Only the key results (statistically and operationally) need to be included. Only include results that you have absolute confidence in. Validation is about building confidence in a system and this comes from confidence in the results.
- *Review process* – The document must be formally reviewed by experts who had no direct input into the authoring of the report. Since different levels of management will read the document it is useful to include readers from these levels in the review process.
- *Results Transfer* – Transfer information to cases (This should include the input of results into the VDR).

NB. A 'report' is often a product that has been sponsored by a customer. It must often satisfy certain success criteria of the customer who will then use it to provide information to other stakeholders in order to enable them to make a fair assessment of the system. Any shortcomings in the validation strategy and/or negative results should be identified and justified.

STEP 4 Determine the Results

Sub-Step 4.3 Prepare and Review Validation Report

Inputs

- Analysis contributions
-

Outputs

- Validation Report (placed in the VDR library if the status is “Public”)
- Identification of Validation Strategy shortcomings
- Information to cases

STEP 5

Disseminate Information to Stakeholders

Sub-Step 5.1

Disseminate information for stakeholders' and decision makers' review using case based approach where available

Description

Throughout the validation process information needs of the stakeholders and decision makers has been used to structure the validation requirements. At major validation milestones they are given consolidated information about the results collected during the validation process to date. The structuring and presentation of evidence shall utilise a case based approach. The objective of the validation process is to provide the decision makers with enough adequate information to enable them to make decisions about the further lifecycle phases of the proposed operational concept.

The main forms used to communicate evidence to stakeholders are:

- Model based Results
- Real time demonstration simulations
- Stakeholder fora
- Reports (focused on single simulations, performance areas or cases)

Points to consider when providing information to the decision makers for review:

- Keep key stakeholders 'in the loop'. As soon as preliminary results are available, interim presentations should be made. These will sketch out initial findings and preliminary results. It is important to make the customer aware that these are preliminary results that may change as analysis continues.
- Results should not be reported to stakeholders until there is consent within the Validation Team about the validity of evidence. The traceability exercised in the Analysis Contributions will be useful here.
- Different stakeholders will have a different idea of what the key results are. Therefore structuring the information is important. The Analysis Contributions can be used here in lieu of the main report as these should have information on all the objectives assessed during the exercise.
- The validation practitioners should not try to influence the stakeholders' decisions or let the stakeholders influence their findings. They must remain completely impartial in their presentation of the results.

The evidence presented to the stakeholders must show how the performance and/or behaviour of the ATM System should be improved as a result of implementation of the proposed concept. A key issue is to be able to provide the evidence of how any current or forecast barriers to improving performance have been addressed.

Inputs

- Analysis Contributions
- Validation Report

Outputs

- Model based demonstrations and Real Time demonstrations
- Information delivered to Stakeholders
- Stakeholder feedback on results or demonstrations

Description

Throughout this methodology a major principle has been that it is not the validation team that will draw conclusions about the success or failure of the concept or project. This is the responsibility of the stakeholders. Using the information supplied in Sub-Step 5.1 the stakeholders can draw their conclusions. Since the validation team will have an in-depth knowledge of the validation activity and results at this stage they should be available should the stakeholders require any further information or guidance.

Once conclusions have been drawn the next logical step is to decide on actions that need to be taken. Some actions will have an impact on the current programme or project and require modification to the existing Validation Strategy. Other conclusions may not have a direct impact on the current programme but will feed into the validation strategy for future projects or programmes that may occur if it is decided to progress the concept to the next stage of the lifecycle model.

Thus, although this sub-step may be the final validation activity in a programme, the output of this activity may be one of the first inputs into a new programme.

Inputs

- Analysis Contributions
- Validation Report
- Interim presentations, reports and information
- Key stakeholder feedback

Outputs

- Conclusions and actions.
- Feedback and modification to Validation Strategy



Glossary

ANALYSIS REQUIREMENTS: A set of requirements detailing what will be needed in order to collect and analyse all the data necessary for the analysis. (See Sub-Step2.9)

ANALYSIS SPECIFICATION: A plan detailing how the indicators and metrics will be analysed, including information on Exercise Validation Objectives addressed, data collection methods, analysis methods, statistical hypothesis, operational and statistical significance and outline reporting plans. (See Sub-Step2.6)

ASSESSMENT: An evaluation based on engineering or operational judgment and/or analytic methods. (EATMP Glossary)

ASSUMPTION: A thing (an idea or statement) that is considered as true (to allow further progress). (OED) Assumptions are considered as true in order to allow a possibility to be explored or a hypothesis to be tested. It is critical to remember that a validation result is only as good as the assumptions on which it is based. Assumptions define the range of conditions for which a validation result is applicable. Assumptions can be expected to be challenged.

ATM PROBLEM: Statement, generally provided by a development team, of the type of air traffic management problem to be solved (indicating performance requirements), the components of the ATM system involved and limitations on communications and other infrastructure issues. The statement may also include the geographic location and timeframe of the problem and typically relates to one or more of the ATM 2000+ Strategy Objective (See Sub-Step 0.1)

ATM SYSTEM: Set of distributed components co-operating in order to provide ATM services to airspace users.

BASELINE: The benchmark against which the organisations will be measured; in ATC terms, a defined set of tools, procedures and airspace design

BENEFIT MECHANISM: The means by which a benefit is produced. (After OED)

DATALOGGING REQUIREMENTS: A set of requirements placed upon the platform team by the validation team to detail all the parameters expected to be logged by the simulator and a common format for the log message. (See Sub-Step2.9)

DETAILED EXERCISE DESIGN: A detailed, scientific structure for the specification of the exercise runs, to ensure that the results from the runs provide suitable data to enable the analysis specified in the Analysis Plan to be carried out and thus to provide robust evidence to confirm or deny the hypotheses developed for the validation exercise. (See Sub-Step2.6)

EVALUATION: To form an idea of the amount, number, or value of; assess (OED). The objective is to establish a reliable, absolute or comparative measure of performance or behaviour for the 'element being evaluated' which is to be used in support of subsequent decision making (See 'assessment' for additional clarification).

EXERCISE PLAN: A detailed description of the scope, purpose, and planning of an individual exercise. (See Sub-Step2.6)

EXERCISE RUN: One timetabled unit in the Validation Exercise. An Exercise Run will have specific Organisation, Traffic Sample and possible seating plan.

EXERCISE VALIDATION OBJECTIVE: A statement of what the validation team will work towards at an experiment level in order to address a higher, Programme or Project Validation Objective. (See Sub-Step 2.2)

FAST-TIME SIMULATION: Analytical modelling technique that analyses air traffic improvements based on an analytical model that represents the displacement of traffic over time, with the models usually incorporating rule-based decisions that control the interactions between the actors being simulated.

FIDELITY: Degree to which a model or inputs match the characteristics of the real system it represents.

HYPOTHESIS: A supposition or proposed explanation made on the basis of limited evidence as a starting point for further investigation (OED). A hypothesis is stated so that it may be tested. Consequently it is important that the hypothesis is expressed in a testable form.

INDICATOR: A Measure of Merit used to check whether a particular requirement has been met that is indirectly related to the objective of interest.

JUDGEMENTAL TECHNIQUE: Validation technique in which the opinions of a panel of carefully-selected individuals with specific knowledge on an operational concept being validated are collected and may be revised, providing evidence to support the hypotheses of a validation exercise.

KEY PERFORMANCE AREA: An area defined as most important in determining whether a system has been improved by a new operational measure e.g. safety, delay, cost-effectiveness, predictability, access, flexibility, flight efficiency, availability, environment and equity. (See Sub-Step1.4)

LEVEL OF CONFIDENCE: The extent to which measurements made during a validation exercise represent a systematic change, rather than occurring purely by chance.

LEVEL OF MATURITY: A statement of a concept's stage in the development lifecycle. There are 6 levels of increasing maturity ranging from 'ATM Needs' (V0) to Implementation (V5).

LITERATURE STUDY: Validation technique which identifies suitable reference material, from which relevant parts of the content are documented and analysed to derive evidence to support the hypotheses of a validation exercise.

METRIC: An ordinal measurement of a system parameter that is directly related to the objective of interest.

OPERATIONAL CONCEPT: Description of a set of ATM components and the manner in which they are configured and operated. The ATM Operational Concept should address a specific ATM problem. A statement of the operational concept, generally provided by the development team, should provide information on the actors involved and their tasks and responsibilities, enablers, events and the drivers of the events, processes and their relation to each other, airspace organisation, information flows and procedures. (See Sub-Step0.2)

OPERATIONAL CONCEPT VALIDATION: The iterative process by which the fitness-for-purpose of a new system or operational concept being developed is established.

OPERATIONAL SCENARIO: A documented description of a sequence of events involving one or more 'actors' that is focused on some specific ATM function or procedure. This type of scenario is generally implemented during initial concept design and development phases. Operational scenarios are a tool that allows practitioners to describe and test the concept and its intended uses.

OPERATIONAL IMPROVEMENT: Any operational measure or action taken to improve the baseline provision of ATM operations.

ORGANISATION: A term used to describe a set of conditions that will be simulated together. In ATC terms, a defined set of tools, procedures and airspace design. Often used to differentiate a Baseline Organisation from Advanced Organisations (where different aspects of an ATC concepts will be simulated) in order to determine benefits of the concept.

PARAMETER: One of a set of measurable factors that define a system and determine its behaviour and are varied in a validation exercise.

PLATFORM SCENARIO REQUIREMENTS: Set of requirements that must be represented on a validation platform for a particular validation, consisting of ATM components, fidelity requirements, geographical requirements and time-based requirements, taking into account the constraints on the validation. (See Sub-Step2.5)

PROGRAMME VALIDATION OBJECTIVE: A statement of what the validation team will work towards at a programme level in order to address the Stakeholders' Needs and Validation Expectations. They should cover broad topics such as scope of the validation, what should be achieved at each stage in the development lifecycle, what can be achieved at each stage of the validation process, ATM Key Performance Areas (KPA) and technical issue (See Sub-Step1.4)

PROJECT VALIDATION OBJECTIVE: A statement of what the validation team will work towards at a project level in order to address a particular aspect of one or more Programme Validation Objectives. (See Sub-Step2.2)

QUALITATIVE ANALYSIS: Analysis that aims to extract meaning and conclusions from a set of non-numerical data, without necessarily giving a specific numerical result.

QUANTITATIVE ANALYSIS: Analysis that aims to reach a specific numerical conclusion, often with an associated level of confidence.

REAL-TIME TECHNIQUE: Validation technique consisting of the participation of one or more subject-matter experts (e.g., controllers or pilots), who perform their operational tasks in a real-time environment, and the subsequent assessment of the experts' responses and decision making. This includes real-time simulation, operational trials and field tests.

SCOPE OF ATM PROBLEM: Set of components within the overall ATM process that relate to the ATM Problem and which must be represented on the validation platform.

SHADOW-MODE TECHNIQUE: Validation technique in which the new system is given live feeds in the operational environment and runs in parallel to the operational system. There are 3 different types of shadow mode trials - Passive, Active and Advanced (sometimes called 'reverse' or 'hot' shadow mode). In Passive Mode, the new system will be non-interfering and will not play an active part in the ATM system. In Active Mode the new system can be provided to a user in parallel with the current system and thereby play a more active role in actual operations. In Advanced Mode the new system will be put in active operation with the old system run in parallel as a fallback.

SIMULATION: A validation exercise performed using a simulator.

STAKEHOLDERS: Actors in the ATM service whose support, co-operation and advice is essential in ensuring that a proposed operational concept can be brought into service.

STAKEHOLDERS' ACCEPTANCE CRITERIA: A set of criteria reflecting what the stakeholders will consider acceptable performance of the concept during the review process. (See Sub-Step2.1)

STAKEHOLDERS' NEEDS: A high level description of the various concerns, requirements and objectives each stakeholder has from the validation process. (See Sub-Step1.1)

TECHNIQUE: A generic, high-level approach taken to perform a task. In relation to validation, this includes techniques for the overall validation of the operational concept, the approach for analysis and the approach taking measurements of the metrics.

TEST: A procedure intended to establish the quality, performance, or reliability of something (OED).

TOOL: The means, usually computer-based, of making a method quicker or easier to perform.

TRANSITION CRITERIA: A set of criteria a concept must meet in order to progress from one level of maturity to the next. There should be Transition Criteria for each case identified in the validation process, e.g. Safety Case, Human Factors Case. (See Sub-Step1.2)

VALIDATION: To agree the truth or value of something (OED). (See Operational Concept Validation)

VALIDATION ACTIVITY: Each individual activity performed during the course of a validation exercise.

VALIDATION EXERCISE: An individual exercise (e.g. study, experiment, demonstration, trial) in which an ATM concept is assessed.

VALIDATION EXPECTATIONS: A description of the various concerns, requirements and objectives the validation team has from the validation process. (See Sub-Step1.3)

VALIDATION PLATFORM: Collection of integrated tools that, together, provide a resource for the running of a validation exercise and which may itself be further enhanced in functionality by the addition of tools for a specific activity. It is not necessarily a single monolithic installation, and may be used to describe an integrated set of equipment and facilities dispersed over a wide geographic area.

VALIDATION PROCESS: Process which encompasses overall validation, defining the tasks to be performed to validate a system from the time the system is first identified as a subject to be validated until the validated system is in operation.

VALIDATION REQUIREMENTS: A statement of what is required from the validation process as outlined in the Validation Expectations for each of the remaining phases of the development lifecycle in order to address the Project and Exercise Validation Objectives. (See Sub-Steps1.5 and 2.2)

VALIDATION SCENARIO: A description of the events, actors, and interactions of an Operational Scenario when applied in a simulation environment. The objective is to excite the performance and interactions described or expected in the operational scenarios. The simulation environment refers to various configurations of airspace, traffic sample, weather, failure modes, and any other controllable variables that might affect the performance of the ATM system. Validation scenarios are actually run in the exercises, therefore they will require specific traffic files, airspace files, and possibly scripted events in order to execute properly. They will also have associated validation objectives and be able to address specific indicators and metrics.

VALIDATION SCOPE: Clear, precise statement of the coverage of a set of validation tests/trials to be conducted on a particular ATM Scope.

VALIDATION STRATEGY: Framework for specifying and performing a set of validation activities, defining reference models, techniques, methods and rules to structure and standardise validation. (See Sub-Steps1.5, 1.7 and 2.3)

V-MODEL: A model which used to define a set of uniform procedures for system or software development, e.g. (Ref 8).

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List of Acronyms

ATM	Air Traffic Management
AP5	FAA/EUROCONTROL Joint Action Plan 5 Validation and Verification Strategies
CAATS/CAATS II	EC 6th Framework project – Cooperative Approach to Air Traffic Services
EC	European Commission
ECAC	European Civil Aviation Conference
FAA	Federal Aviation Authority
HMI	Human Machine Interface
JPB	Joint Programme Board
JPDO	Joint Planning and Development Office
ISA	Instantaneous Self-Assessment
KPA	Key Performance Area
OCSVD	FAA/EUROCONTROL Operational Concept Strategy Validation Document (AP5)
OED	Oxford English Dictionary
PRC	Performance Review Commission
R&D	Research and Development
STATFOR	Specialist Panel on Air Traffic Statistics & Forecasts
TLX	Task Load Index (NASA)
VDR	Validation Data Repository

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