

**EUROPEAN
Operational Concept
Validation Methodology
(OCVM, ...)**

“Establishing fitness-for-purpose”

*“The 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**

**EUROPEAN AIR TRAFFIC
MANAGEMENT PROGRAMME**



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JPB message on validation

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**Project leaders of EC
and EUROCONTROL ATM related projects**

(see distribution list)

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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1. Foreword

1.1 Background

The annual global European ATM R&D investment amounts typically to about 200 M€.

It is expected that this amount will remain stable or even increase in the next years through the build up of the EC Single European Sky (SES) initiative and the ATM Master Plan development and implementation.

The average size of the projects however is small (~0.8 M€) and thereby the total number of projects and participating organisations is high.

As a consequence of this fragmentation there is a lack of consistency between the different projects in how objectives are set and how results are captured. There is no shared view of a common target system or, more importantly, the goals to be achieved by that system, or on the approach to develop it.

As a result, despite all efforts, there is little transfer from R&D to operations.

1.2 History

Since the mid 90'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, sparking the "Validation Debate". The EC provided a platform for that debate bringing together industry, R&D organisations, Air Traffic Service Providers (ATSPs) 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) 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) 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.

The VGH was broadly disseminated by the MAEVA project. The Agency made it a reference document in its EATM Management Handbook. MAEVA organized 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). OCVM and VDR are harmonised and support each other. In 2004 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. The VDR provides a data structure to fully support E-OCVM and mutual awareness of the progress of validation.

1.3 Solution

The most important information going into validation are descriptions of:

1. The problem and its solution,
2. Stakeholder issues and needs.

Based around these two sets of information expected outcomes can be described for development programmes allowing realistic validation objectives to be set. It is by having realistic objectives from programme level down to experimental level that the quality of information coming from R&D projects can be

1. Foreword

improved and will thus provide more useful support to the managers that make implementation decisions. The European Operational Concept Validation Methodology (E-OCVM) uses three views to help ensure that validation objectives are realistic:

- The **'concept life cycle'** view. It is used to map out the evaluation exercises needed to determine concept performance and behavioural capabilities.
- The **'stepped evaluation'** view. It provides a logical structure to the evaluation of the performance and behavioural characteristics of an ATM concept.
- The **'case based'** view. The information generated by various tests and experiments needs to be gathered together in a way that helps explain to the stakeholders what can be expected in terms of performance and behavioural capabilities. From this information costs and benefits can be derived.

Validation Information Storage and Dissemination via the Validation Data Repository (VDR) is an integral part of the methodology.

E-OCVM does not reflect specific organisational details of any establishment. Therefore it allows any establishment to work in a common framework regardless of their specific set up.

1.4 Benefits

E-OCVM together with the VDR provide a structure for the

- macro management of improvements of the European ATM System,
- management of the individual projects and experiments that will make up the European ATM Programme.

They enforce the linking between programme objectives and corporate needs and focus individual experiments on the identified needs ("business case"). They also help to identify realistic objectives that will help to develop R&D projects into solutions that can be imple-

mented.

The iterative nature of the methodology keeps the individual long term programmes in line with evolving corporate capabilities and needs. At the same time the improved knowledge gained through the experiments will impact the evolution of the capabilities and corporate needs.

E-OCVM and VDR together enable the co-operation of different organisations in a consistent approach providing mutual visibility of the progress of work.

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

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

- Director ATM research (EUROCONTROL Agency);
- Director ATM strategies (EUROCONTROL Agency);
- Head of Aeronautics unit (European Commission, DG RTD);
- Head of ATM unit (European Commission, DG TREN);

In January 2005 the JPB members 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 relevant partners there is also the need to further maintain them and incorporate experiences of their users. There is the need to provide support to E-OCVM and VDR users. In addition, users of E-OCVM and VDR must be provided with support.

JPB also requested the EUROCONTROL Agency to organise a Validation User Group (VALUG). It shall provide a forum to bring together all projects that contribute to the validation of future European ATM concepts in order to explain and advertise the methodolo-

gy, to exchange experiences and best practices and to further extend and improve the methodology. The technical entry point to the Validation User Group is the web site

www.eurocontrol.int/valug

This web site makes the methodology itself, the Validation Data Repository and more information available. It provides contacts to the User Group. Everybody is invited to visit this site, to join and to contribute to the User Group.

1.6 Document Structure

The document is in two parts:

- Part I gives an overview of the need for an Operational Concept Validation Methodology;
- Part II gives a detailed breakdown of the tasks and issues that should be addressed with each step of the methodology.

PART I - INTRODUCTION

1. Introduction

1.1 The ATM community need

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 2) 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.

Principle 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 principle 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.

The reference point for future ATM performance needs is the ATM2000+ Strategy (Ref CAATS). According to ATM 2000+ Strategy the types of benefits that ATM enhancements are expected to deliver are:

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

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

- Acceptable to those that operate the ATM system – e.g. controllers and pilots. (OPERABILITY)

There are other issues that should be addressed depending on the nature of the ATM Concept being developed but the above performance characteristics are universally important.

(NB. Any solution targeted at a specific performance area will also need to be evaluated for its impact on the other key performance areas).

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

1.3 The problem space

Assumption: ATM R&D has a poor record in implementing solutions because

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

Ideas developed within R&D have a poor record in terms of implementation generally because the 'decision making stakeholders' are not sufficiently convinced by the information provided by R&D to be persuaded in any particular direction.

This proposal focuses on providing a methodology to identify stakeholder information needs and then use these information needs as a principle (but not sole) driver for the evaluation of proposed concepts. i.e. a 'Concept Validation Methodology'.

It is considered that for a 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, description below),
- **Relevancy** – has two aspects, relevancy of the idea 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 (c.f. the Action Plan 5 proposal on Maturity life cycle model, described briefly below).

1.4 Operational Concept Validation

Validation as a term has wide usage. Generally it is used to describe a process of checking that requirements have been satisfied. In the context of this methodology it will be assumed that requirements (user, operational, technical, safety, etc) are not mature and thus cannot be used as the basis for validating ideas still at an early stage of development. In order to show that the focus of this methodology lies in the concept stages of developing an idea into a full application (see Concept Levels of Maturity next section) the term 'Concept Validation' has been chosen.

This document uses the CAATS (Ref CAATS Glossary) definition of Validation:

"The 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 4). This document only addresses 'validation'

Operational Concept Validation is therefore considered as the process of determining stakeholders' information needs about the performance and behavioural capabilities of an ATM Concept and then structuring an evaluation programme to provide information that addresses those information needs.

1. Introduction

The information should describe the potential added value of the concept and identify constraints or enablers needed to realise it. Performance and behavioural capabilities are terms that can be used to help structure the information needs because the information should be presented in ways that enable the stakeholders to decide whether to continue development beyond the concept stage into industrialisation and eventually implementation.

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 (an improvement has been identified);

Or

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

'Concept Validation' should be objective and transparent in order to support the decision making process where the many different stakeholders have different information needs and sometimes conflicting requirements.

To support 'transparency' there is a need for 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

Where applicable, stating that the system has a negative impact 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.

Concept Validation naturally encompasses the need for information about Safety issues. There are two reasons for this. The first is simple in that 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. Operational Concept Validation Methodology Overview

The following 'Operational Concept Validation Methodology' is described using three different 'views'. Each addresses different aspects of the evaluation process:

- The **'concept life cycle'** view. In order to ensure against unrealistic expectations being placed upon experimental teams there is a need to create a 'Validation Strategy and Plan at the level of 'Programme' management'. Such a plan would be created at the start of each stage of the Concept Life Cycle – focussing on the next step and outlining also the remaining other steps. This 'Validation Strategy and Plan' should be used to map out the evaluation exercises needed to determine concept performance and behavioural capabilities. The 'life cycle' describes typical information that can be expected from the evaluation process during each phase of the concept development life cycle.
- The **'stepped evaluation'** view. For each experiment/assessment, as identified in the 'Validation Strategy and plan' there is a series of experimental 'steps' which together provide a logical structure to the evaluation of the performance and behavioural characteristics of an ATM concept.
- The **'case based'** view. The information generated by various tests and experiments needs to be gathered together in a way that helps explain to the stakeholders what can be expected in terms of performance and behavioural capabilities. From this information costs and benefits can be derived.

The information on performance and behaviours " should address:

- Corporate Performance Areas (safety, capacity, economics, environment, human involvement);
- Experimental objectives (workload, usability, hazard analysis),

These can be formalised in a 'case' format e.g. Safety case, Human Factors case etc.

2.1 Concept life cycle view

The assumption is that an ATM Concept will take time to develop into an application and that the testing process should allow for this 'maturing' process. Too much rigour too early will stop a good idea whereas too little rigour late in development will allow a poor idea to go forward. As the concept matures 'programme managers' should be aware of what can be expected in terms of results and the reliability of those results in order to set realistic programme and project objectives.

The following 'maturity model' is taken from the work of the FAA/EUROCONTROL Action Plan 5 Validation group and is documented in the Operational Concept Validation Strategy Document available at

<http://www.eurocontrol.int/faa-euro/start.html> (Ref 5). The FAA/EUROCONTROL OCVSD proposes a 5 level concept maturity scale ranging from V1 (idea) to V5 (Implementation). At each of the stages the validation scope is likely to mature in line with the advancing maturity of the concept (Figure 1). As the concept becomes more mature, the validation activity must become more rigorous. Experiments may be larger and the focus of these experiments and their objectives are likely to mature.

ATM Concepts - Levels of Maturity

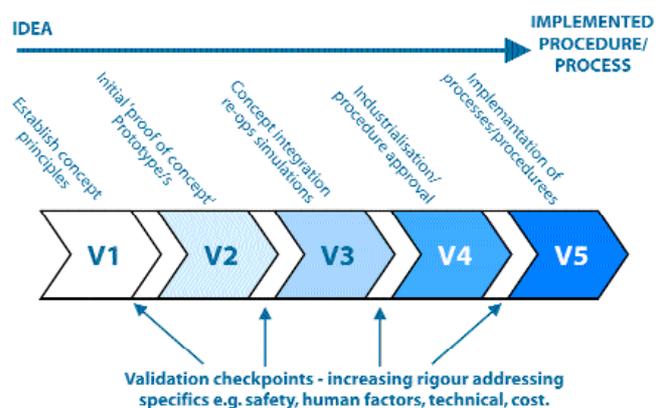


Figure 1: The Action Plan 5 concept maturity model

2. Operational Concept Validation Methodology Overview

The previous model requires further development to determine the type of experimentation and assessment that should be considered appropriate at each phase of development.

The 'Concept Validation Methodology' described in this document can be seen to be most applicable to the first three phases from the AP5 maturity model (i.e. V1, V2 and V3). As soon as industrialisation (V4), procedures approval and finally implementation issues (V5) become the focus of the validation plan more rigorous evaluation methodologies than those proposed here will be required.

2.2 Stepped evaluation view

The Validation Methodology is presented in a numbered list format – a stepped approach. Each step in the numbered list details the tasks involved in that step and 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:

Understanding the problem addressed and the proposed solution. Outlining exactly where the problem lies, measuring the severity of the problem and understanding how the solution proposes to remedy this problem.

1. Set Validation Strategy:

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.

2. Determine the Experimental Needs: Select the tool or technique, prepare the validation plan, validation

platform and prepare for studies and experiments.

3. Conduct the Experiment:

Conduct the studies and carry out the experiments.

4. Determine the Results:

Analyse simulation results and review against original aims and objectives.

5. Prepare Information for Stakeholder Review:

Develop and disseminate conclusions.

The above steps are shown in more detail in the table below (Figure 2) with a full description of each sub-step is provide in Part II of this document.

As the chart below indicates steps 0 and 1 would be completed at the beginning of a development phase in the development life cycle probably by a Programme management level team.

Steps 2, 3 and 4 would occur several times as an idea matures through different phases and through different projects. The idea is that each specific project targeted at development of some aspect of the idea would go through these steps in order to ensure reasonable design of the evaluation (validation) process.

Step 5 is the preparation of material to disseminate to stakeholders. This should occur at significant points through the life of an idea. Special reference to the end points of each of the life cycle maturity model phases should be made where it is expected that stakeholder's views would impact the decision to progress with development into the next phase.

The following table is intended as a readily available guide to the main steps, sub-steps and expected outputs from this process.

Step	Sub-step	Name	Output
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 or Operational Improvement(s) Typical scenarios Alternatives Analysis
1. Set Validation Strategy	1.1	Identify the Stakeholders, their needs, issues, involvement and 'typical questions that require answering.	List of Stakeholders Stakeholder Issues and questions to be answered.
	1.2	Identify the Level of Maturity to ensure expectations are realistic with information already available	Statement of level of Maturity and potential validation needs
	1.3	Describe (Validation) Expected Outcomes-outcomes, products, what will success look like	Validation Expected Outcomes
	1.4	Identify High Level Performance Objectives in key Performance Areas	List of High Level Validation Objectives and Key Performance Areas
	1.5	Establish Initial Validation Needs, potential scope and draft plan	Draft Validation Plan
	1.6	Select Validation Tools or Techniques	Decision on tool(s) or technique(s) to be used
	1.7	Define Validation Strategy, plan, potential projects	Validation Strategy and Plan
2. Determine the Experimental Needs	2.1	Identify Stakeholder Acceptance Criteria and Performance Requirements	List of Acceptance Criteria and Performance Requirements
	2.2	Identify Low Level Validation Objectives	List of Low Level Validation Objectives
	2.3	Refine Validation Strategy	Refined Validation Strategy
	2.4	Identify Indicators and Metrics	List of Indicators and Metrics Datalogging Specification
	2.5	Specify Scenarios	Scenario Specification Traffic Samples
	2.6	Produce Experimental Plan	Experimental Plan
	2.7	Produce Analysis Plan	Analysis Plan
	2.8	Produce Detailed Experimental Design	Detailed Experimental Design
	2.9	Identify Assessment Requirements- what is required to enable the assessment to take place?	Sets of Assessment Requirements
	2.10	Prepare the Platform or Facility	Prepared and Configured tested Platform
	2.11	Conduct Pre Exercise Testing	Tested Validation Platform
3. Conduct the Experiment	3.1	Conduct Validation Experiment	"Raw" data Record of system parameters recording status of validation platform
	3.2	Assess for unexpected effects or behaviours	Concept Problem reports
4. Determine the Results	4.1	Perform Analysis specified in the Analysis Plan	Analysed Data
	4.2	Prepare Analysis Contributions	Analysis Contributions
	4.3	Prepare Validation Report	Validation Report
5. Information for Dissemination	5.1	Disseminate Information to stakeholders and decision makers	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

2. Operational Concept Validation Methodology Overview

The following chart (Figure 3) shows the principle feedback loops that should support review after an experiment and at project or programme completion. The question that should provoke a review of the experiment, validation strategy or even operational concept is; 'Was the outcome as expected' (Ref Sub step 1.2 Validation expected outcomes.)

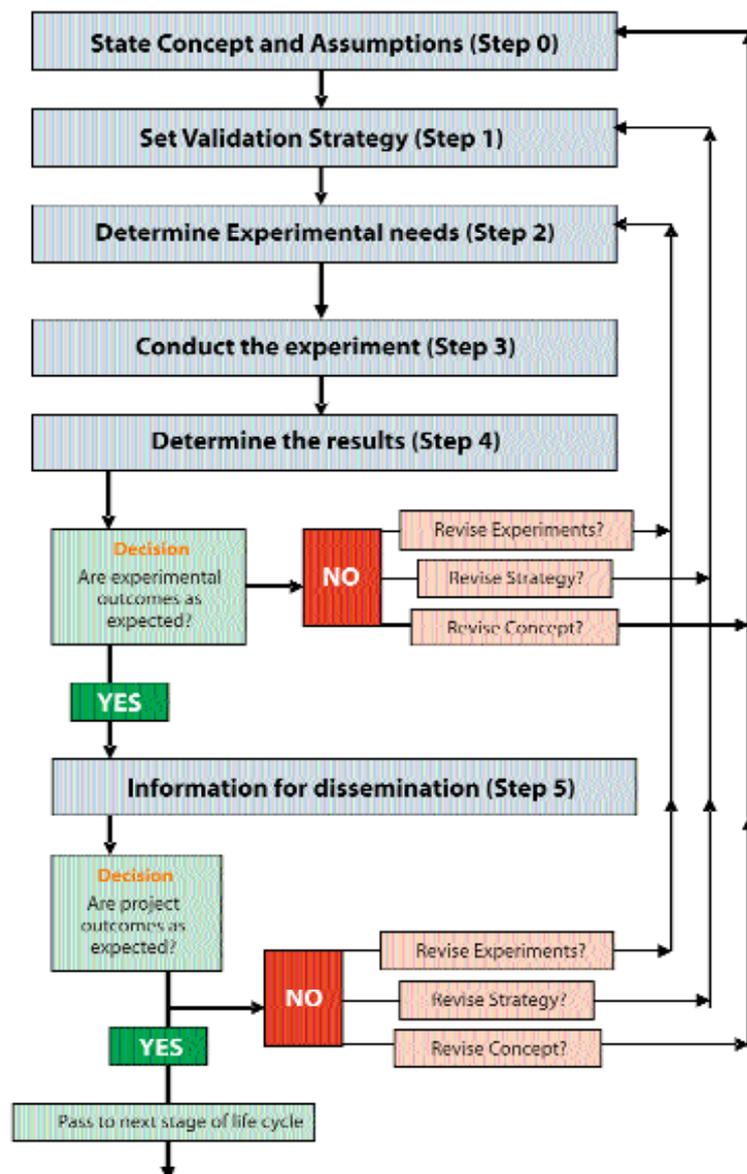


Figure 3: Flow chart showing review points of experiments, strategy and concept.

2.3 Case based view.

This part of the 'Concept Validation Methodology' is focused on describing the type of information that should be expected from the validation process and how that information could be structured in order to ensure that it is accessible and understandable to stakeholders who will make decisions about the progress of the 'concept' beyond the world of ATM R&D. Performance based around performance target measures such as safety, capacity, economics and environment need to be identified clearly along the development.

Additionally the results of each individual experiment and assessment from each project that is involved in the development of a 'concept' need to be collated in a format that supports effective communication of expected performance capabilities and behavioural characteristics.

An approach such as the 'case' format is already used for collating certain information i.e. 'safety', 'business' and human factors'. This could be expanded to cover 'environmental' and other aspects that need a specific focus e.g. technical and operational.

The 'case' approach could hold detailed information on performance capabilities and behavioural characteristics. Each case would be developed along the life of the concept. 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.

As this approach is currently a proposal further development would be required if it were considered reasonable to follow this direction.

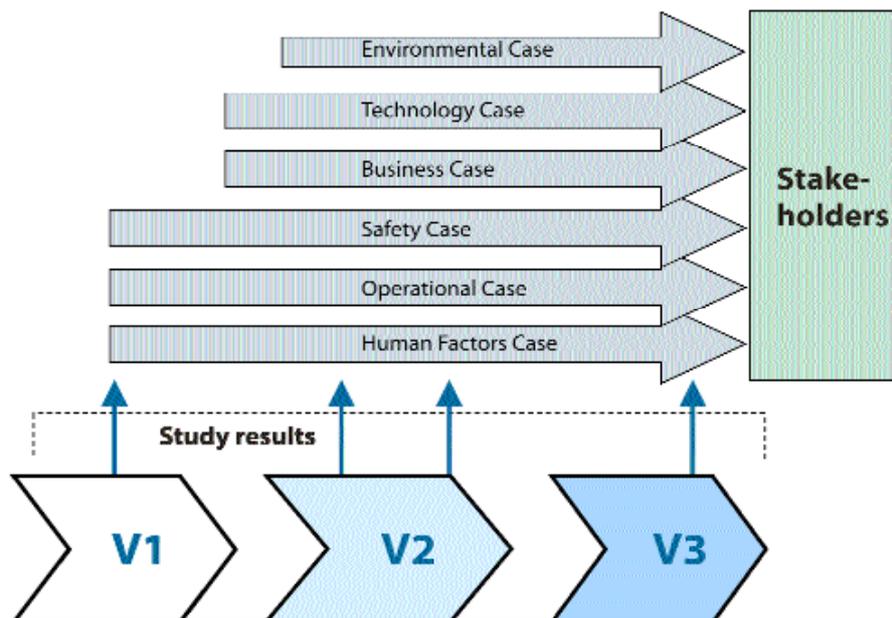


Figure 4 : Studies supplying information to packaged results

3. Validation Information Storage and Dissemination

The availability of information from experiments and other forms of assessment is a key issue in the task of validation.

The E-OCVM approach implies a structured framework for capturing and storing validation information, which if applied generally by programmes would promote mutual understanding and convergence of validation related information between programmes. In other words, a common validation information framework will serve two main purposes:

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

Central to the efficient and effective application of the methodology, therefore, is information management. It is important that arrangements are made within a programme to ensure information is stored using a formal structure, a common format and standard across the constituent 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. It 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 evidence for assertions derived from the work to be seen in the context of the objectives 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, Information for Dissemination,

because it naturally structures the validation information in a meaningful way for Stakeholder assessment and review during project activities and at the end of the overall programme. It provides the means by which a project can present a picture of what it has contributed to the validation of the concept for the programme, and for the programme to present its overall findings based on the work performed by its individual projects.

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. It 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”. The following diagram (Figure 5) summarises the intended context of the VDR.

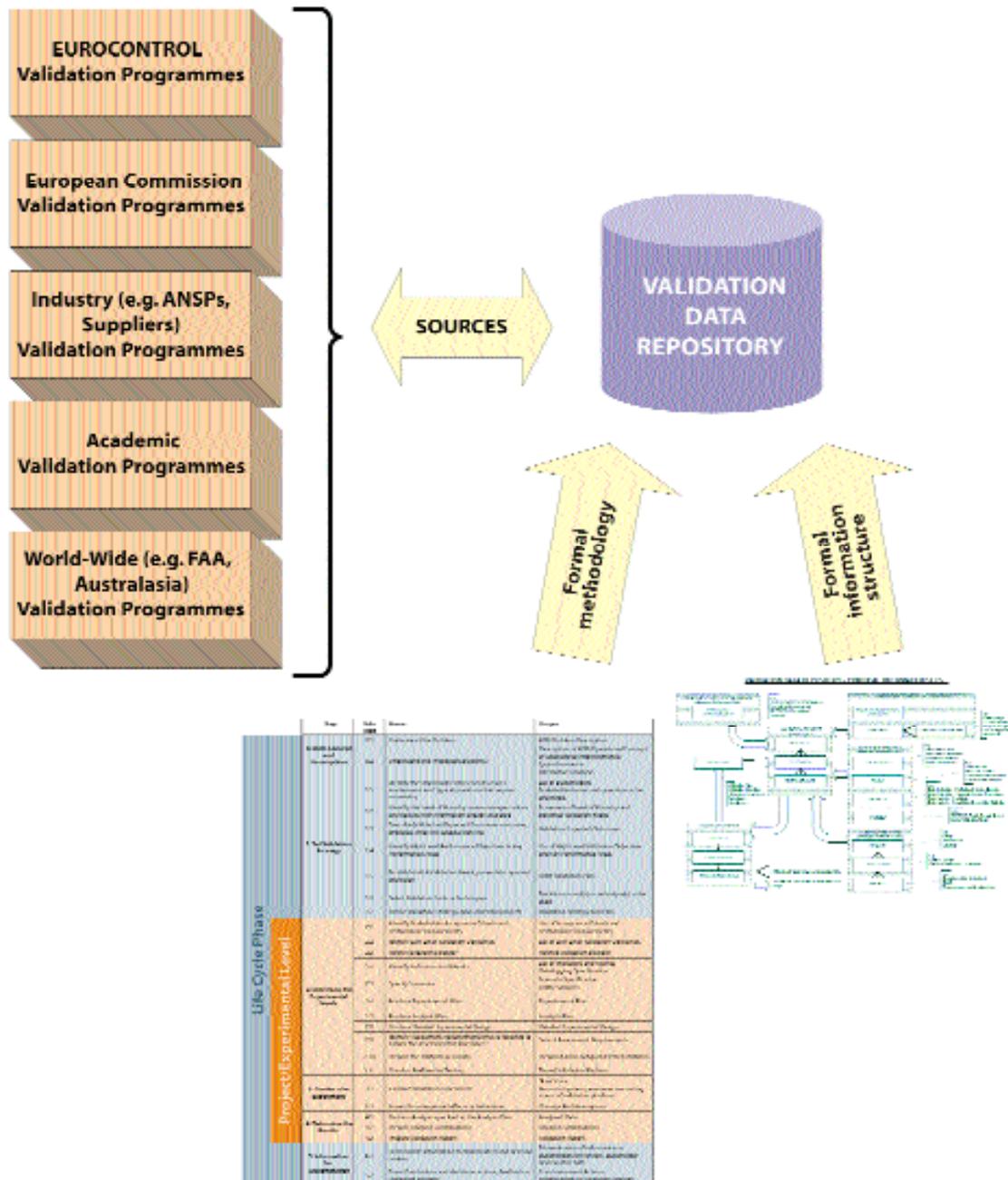


Figure 5: Data movement from projects to the VDR

All programmes should consider using the VDR. Full information about it can be obtained from the VDR web site on www.eurocontrol.int/eatmp/vdr (Ref 6).

4. References

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***PART II - VALIDATION METHODOLOGY:
STEPS 0 TO 5***

STEP 0 State Concept and Assumptions

Activity 0.1 Understand the problem

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 (KPA) e.g. safety, capacity limitations, controller 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 analysis on the current system focusing on the problem areas since later in the validation activity the current performance will be used for benchmarking and for setting hypothesis. For example, delay analysis could be carried out where there is a delay 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 program 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. It is useful to use a detailed template for this activity as it will ensure that all of the ATM problem areas are described in a consistent manner.

Understanding the problem, and thus the customers' needs, in this detail will enable the validation team to tailor a much better validation design.

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

- 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

STEP 0 State Concept and Assumptions

Activity 0.2 Understand the proposed solution(s)

Description

It is the proposed solution - not the problem - that will be validated so a thorough understanding of all aspects is required. As with the ATM problem, analysis should be carried out on the proposed solution. Also remember 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 experiments 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?* – In what way will the proposed solution resolve the ATM problem? e.g. resectorisation, new controller tool, new HMI, new working practice.
- *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 that these constraints are met and judge the impact of them.
- *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 OC or OI 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 is the risk of the proposed solution?* – A final important analysis during this activity is a risk analysis. Any proposed solution will have an inherent risk associated to it in terms of current maturity, level of development required, level of investment required, impact on the baseline system, complexity of the solution etc. This risk 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.

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.

STEP 0 State Concept and Assumptions

Activity 0.2 Understand the proposed solution(s)

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 to be able to compare the positive and negative aspects of these various solutions.

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)
- Typical operational scenarios
- Alternatives Analysis

STEP 1 Set Validation Strategy

Activity 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 the stakeholders. 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. Ranking the importance of each stakeholder (for example in terms of investment or impact from the solution) and then the relative importance of each of their needs or perhaps even the use of Multi Criteria Decision Making (MCDM) software can help here.

Another objective of this consultation is to identify what are the exact information needs of the stakeholders. As mentioned earlier, the stakeholders make their decisions based on information supplied by the project team. Thus it is important to identify the questions that the stakeholder is likely to ask during the validation process. This analysis 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 the stages at which 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:

- At what stage(s) are the 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?

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.

STEP 1 Set Validation Strategy

Activity 1.1 Identify the Stakeholders, their needs and involvement

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
- Initial Stakeholder Analysis (from first consultation), followed by regular subsequent consultations.

STEP 1 Set Validation Strategy

Activity 1.2 Identify the Level of Maturity

Description

The purpose of this stage is to identify what already exists in terms of concept description and analysis and thus help to determine what the programme or project should set as expected outcomes for the next validation phase.

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). The 'maturity' is linked to the available detail of the concept description. The level of maturity will help define the type, rigour and scope of the validation process.

To help classify the stages in the concept development lifecycle, the FAA/EUROCONTROL Operational Concept Validation Strategy Document (OCVSD) (Ref. 2) identifies 5 main phases. Taking a concept from 'idea' to 'implementation' the concept will pass through 5 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 5 phases are:

- V1. Idea** - Observation, reporting, and agreement on the basic principles and expected benefits of a new concept.
- V2. Initial Prototype** - Initial proof of concept through model or early prototype, full operational requirements build, testing for non-nominal behaviours. 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. Full Concept Specification** - Full specification of concept, pre-operational demonstration, proposed changes to operating procedures, final performance testing. This is the phase for large real time simulations and use of fast time capacity models. This stage will establish the performance of the new system and finalise requirements to hand off to the next phase.
- V4. Industrialisation** - Production, integration, and verification of components (factory acceptance); (Out of direct scope for R&D).
- V5. Implementation** - Sign-off for operation through on-site formal validation. (Out of direct scope for R&D).

During each of these 5 phases there is the potential for iterations. This process of continued design and testing as the concept develops and matures, is illustrated in figure 6 below.

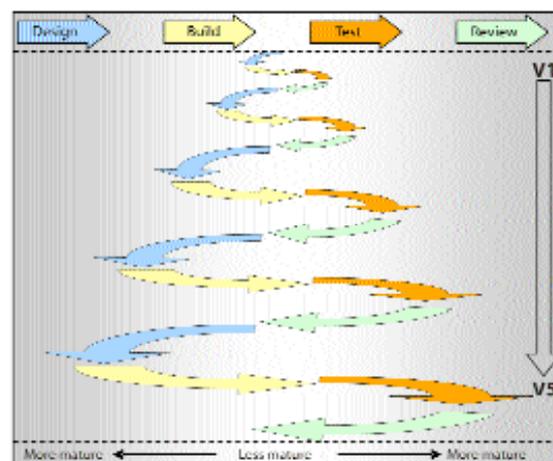


Figure 6: The concept development process at each level of maturity

STEP 1 Set Validation Strategy

Activity 1.2 Identify the Level of Maturity

The first step in this activity is to establish the concept's current level of maturity. Most new concepts will obviously start at V1. They may progress quickly through this phase for example, if they are variations of older, developed concepts.

The progression from one level to the next should be based around clearly defined transition requirements. These requirements will come from the stakeholders and should be set for each of the main stakeholder interest groups. As a minimum, transition requirements should be set for a Safety Case, a Human Factors case, a Business case and a Technology case. Once the requirements have been set the evaluation process can begin and the first part of this will be to set out the validation aim. This is the first stage in the validation design. The validation aim will have a major impact on the shape of the validation activity to come and the type of experiments or studies. The stakeholder requirements will then form the basis of the validation criteria for these experiments.

After the experiments and studies have been carried out if the criteria are satisfied then transition to the next level is possible. If the 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 iterations of the development process given the rapid, dynamic development of the concept. This means that at lower levels 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. Figure 5 on the previous page, illustrates the spiral approach of concept development at each level of maturity, with the validation activity growing in fidelity as the concept reaches maturity.

Inputs

- Description of Proposed Concept
- Body of existing evidence from previous validation work.

Outputs

- Statement of level of maturity and potential validation needs.

STEP 1 Set Validation Strategy

Activity 1.3 Describe (Validation) Expected Outcomes

Description

Validation Expected Outcomes are very similar in use to the term validation aims. The use of the word 'expectation' is to help the user of this methodology to understand that many different people will have expectations about what a successful outcome could be given the ATM problem, the stakeholders will have some initial ideas of what they see as an acceptable outcome or 'final product'. These ideas form the basis of the validation expectations, which 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 in each of the different phases of the development lifecycle?
- What do the stakeholders expect from the validation process in each of the different phases of the development lifecycle?
- What would be an acceptable validation product at the end of each development lifecycle phase?
- What is the scope of the validation at this stage in the concept's lifecycle?
- What specifically will validation address?

N.B. It must be clear that these are Validation expectations and not project expectations. The project expectations will generally refer to how the proposed concept aims to solve the original ATM problem. The validation expectations are concerned mainly with what validation will contribute to the concept's development.

Inputs

- Statement of level of maturity and potential validation needs.
- Information from Stakeholders

Outputs

- Validation Expected Outcomes

STEP 1 Set Validation Strategy

Activity 1.4 Identify High Level Validation Objectives and Key Performance Areas

Description

The high level objectives reflect the stakeholder needs and the expectations of the programme. 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 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 being critical to the programme's success or failure and as such are known as Key Performance Areas (KPA). These also tie in with the strategic high level objectives in the ATM Strategy for the years 2000+ (ref. 3) 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 these benefits are delivered as proposed and assessment of these benefits and benefits mechanisms is likely to form the basis for a large proportion 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 project 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 should 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 not necessary yet to include any concept specific objectives. At this level, the focus should still be on addressing the problem causes and as such it is possible to come up with a very generic list of High Level Objectives that cover the stakeholders' needs and the ATM KPA. Given the generic nature of this list of objectives it is possible to define them at a programme level and they can be used across each concept or even across projects.

The document "An ATM Performance Measurement system" (ref. 4) discusses ATM KPA (and examples) in detail.

Inputs

- Validation Expected Outcomes
- Information from Stakeholders

Outputs

- List of High Level Validation Objectives and Key Performance Areas.

STEP 1 Set Validation Strategy

Activity 1.5 Establish Initial Validation Needs and draft plan

Description

The purpose of this activity 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 development lifecycle. At a programme level it will often be necessary to provisionally outline a number of experiments to be included in initial contracts or descriptions of work. This activity should provide enough input information to ensure that the number and type of experiments chosen is appropriate. This is a draft of the validation plan.

The choice of simulation type will largely be driven by the validation expectations, programme objectives, the descriptions of the proposed solutions and the validation requirements on such issues as:

- Number of experiments required, e.g. to fully cover scope, to achieve the required statistical relevance;
- High Level Validation Objectives addressed;
- ATM Scope of the platform required;
- Geographic scope of the platform (e.g. airspace);
- Realism required;
- Fidelity of the platform;
- Resources required (Human in the Loop, computer based simulations etc).

These requirements should be gathered and detailed here. At this stage in the methodology it is sufficient to keep these requirements at a similar level to the level of the problem and solution descriptions. Enough information should be gained to at least enable an initial estimate of the number and type of experiments required with perhaps even enough information to choose candidate platforms. Later the methodology will discuss the task of tailoring the choice of simulations to fit the specific needs of the projects and concepts.

Inputs

- Description of the ATM problem and proposed concept
- Validation Expected outcomes
- High Level Validation Objectives

Outputs

- Initial Validation Needs
- Draft Validation Plan

STEP 1 Set Validation Strategy

Activity 1.6 Selection of Validation Tool Type or Technique

Description

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

- Initial Validation Needs (Output of Activity 1.4)
- Capability of platform to support the selected concept and to deliver the data required for evaluation
- Platform availability

The Validation Requirements may suggest the need for more than one experiment and it may be beneficial (indeed it may be necessary) to use more than one tool or technique in these experiments. 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 draw up a list of tools or techniques available for use, listing also their capabilities and limitations. These can then be compared against the validation requirements to see which meet the requirements. The most suitable tool(s) or technique(s) should then be chosen and subsequent validation strategies based around these choices.

Figure 6 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. Traditional approaches (such as the 'Banana Model' detailed in MAEVA) 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 designer to decide which to use and at what stage in the concept's development. Figure 6 illustrates that after any experiment, no matter what the tool or technique, there is a period of analysis or transition before the next experiment will begin. In this way results from previous experiments are used as input for subsequent experiments. There should be no restrictions on which tool or technique is used after any other, so long as the requirements are met and the tool or technique is appropriate.

The OCVSD [2], appendix 1 also provides best practices for Human in the Loop (HITL) experiments.

Inputs

- Validation Expected Outcomes
- High Level Validation Objectives
- Draft validation plan

Outputs

- Identification of candidate tool type(s) or technique(s) to be used.

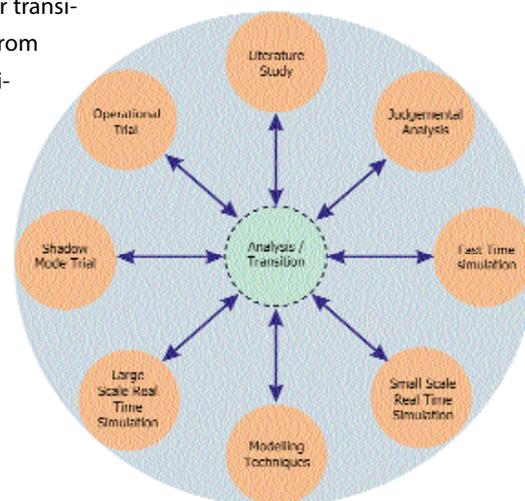


Figure 7: Interactions between tools and techniques

STEP 1 Set Validation Strategy

Activity 1.7 Define Validation Strategy and Plan

Description

This 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 concepts in each of the phases of the development lifecycle.

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

The second purpose of the strategy is to outline the content of these experiments in terms of concepts, scope and objectives addressed. The choice of experiments should strategically address as many of the key high level validation objectives as possible. The ranking of stakeholder needs in Activity 1.3 will act as the main identifier for the choice of which objectives should be addressed. This selection of studies and/or experiments will be necessary to assess if the benefits expected by the stakeholder have in fact been delivered.

At this stage in the process this strategy need not detail individual experimental 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 in order 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 projects there will be a need for many levels of strategy. One may exist for the entire project at a high level, there may be others for different work packages and these may be driven by validation needs and objectives at a concept level. It is important that all the different levels fit together.

Producing a validation strategy can be thought of as a two step process. Firstly, starting at a programme level, a top down approach can be taken to detail:

- High level validation objectives (if applicable, shown per phase of the development cycle);
- Interaction between validation activities of different projects or work packages in the programme;
- Interaction between validation activities of different concepts in the projects or work package;
- Concept level validation objectives taken from concept descriptions, expected benefits and other validation objectives such as assessment needs;
- The strategy can also outline how the activities in the Validation Methodology interact with each other and at programme and project level.

STEP 1 Set Validation Strategy

Activity 1.7 Define Validation Strategy and Plan

The next step takes a different approach - a bottom up approach. This is where the series of experiments and studies are built around the list of validation objectives, first at a concept level, then at project or work package level and finally at a programme level. This phase should take into account:

- **A validation approach** - what sort of studies or experiments are needed in order to address each of the validation objectives.
- **Validation schedule:** The remaining validation milestones need to be scheduled. There need to be a specific schedules for the experiments planned in the next lifecycle phase.
- **Validation resources** - the validation need 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 experiments that can actually be planned will be constrained by money, time, staff, technical limitations such as platform availability and even what experiments have been listed in original contracts such as Descriptions of Work or project proposals.
- **Selection of Studies or Experiments** - Having taken into account the issues given above, a series of studies or experiments can be selected. Each study or experiment may cover a number of objectives for one or more concept.
- **Limitations of studies or experiments** - for whatever reasons it may not be possible to address all validation objectives at this stage (e.g. platform capabilities). Stating what objectives the project 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 studies and experiments** - The list of studies and experiments has been built around the validation objectives. It is also necessary to outline how the studies and experiments are built around each other. This might detail how a particular validation objective is dealt with in more than one experiment or it may detail how the objectives/results of one study or experiment impact on another.
- **Who will carry out the experiments or studies** - Who has the capability to perform the studies or experiments outlined? When can they be carried out?
- **Do the experiments and studies address the high level validation objectives?** - Continuing the building process towards an overall view, it is necessary to review the chosen strategy of objectives and experiments and to see if it addresses as many of the individual validation objectives as possible and ultimately the validation expectations and high level validation objectives. If it does not then the strategy will need revision.

Inputs

- ATM Problem Analysis
- Description of proposed solution
- Validation Expected outcomes
- High Level Validation Objectives
- Draft validation plan
- Choice of Techniques and Tools

Outputs

- Validation Strategy and Plan

STEP 2 Determine the Experimental Needs

Activity 2.1 Identify Acceptance Criteria and Performance Requirements

Description

In Activity 2.1 this methodology introduced the idea of transitions 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 Activities 1.1, 1.2 and 1.3.

Validation is about building confidence in a 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 decide on their confidence in the system, decide if they should accept the concept and/or allow it to progress to the next phase in the development process.

With the emphasis on the concept's performance, it is likely that these benchmarks will be based largely around the various 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 such cases, weight can be added to particular stakeholders, particular expectations and techniques such as Multi Criteria Decision Making (MCDM) can be used.

To help further ease future decisions and clarify the criteria and requirements, the second part of this activity 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) 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 Experimental Needs

Activity 2.1 Identify Acceptance Criteria and Performance Requirements

Inputs

- ATM Problem Description
 - ATM Forecasts
 - Stakeholder analysis
 - Validation Expected Outcomes
 - List of high level validation objectives
-

Outputs

- List of Stakeholder Acceptance Criteria and Performance Requirements.

STEP 2 Determine the Experimental Needs

Activity 2.2 Identify Low Level Validation Objectives

Description

At this stage in the validation process an Outline Validation Strategy should exist in which individual experiments and concepts are listed. There should also be a greater understanding of the concept following the continuing development on it. We are now at a more practical level and so each of the high level validation objectives and KPA can be broken down into validation objectives that can actually be addressed in one or more experiments.

Each of these lower level objectives will address a certain aspect of the programme validation objective / Area of Interest with respect to this particular project and concept. The Stakeholder Acceptance Criteria and Performance Requirements form a key input to this task.

So far in this process, we should have a list of:

1. stakeholder questions;
2. stakeholder information needs;
3. stakeholder performance expectations and requirements;
4. a set of concepts and experiments in which to address points 1, 2 and 3.

It should be the objective of the experiments to provide as many answers, meet as many of the information needs and assess as many of the performance areas as possible. For each of these a 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 validation objectives. For example, if the stakeholder is interested in the controller workload, rather than simply saying the objective is to assess if the effect on workload, the low level objective may say something like "To assess if human resource efficiency can be increased due to a better balance between traffic flows and controller workload following the introduction of {Concept X}".

Given what is known about simulation capabilities and the experiments listed in the Outline Validation Strategy, a list of these validation objectives can be drawn up for each of the experiments. Putting an objective such as this against an experiment is a much more specific, measurable, achievable, realistic and time-framed (SMART) objective.

Another purpose of detailing these lower level objectives is that by listing the objectives in this way it becomes easier to further break down the objectives into indicators and metrics (the next stage in the breakdown).

Inputs

- Validation Strategy and Plan
- List of High Level Validation Objectives and Areas of Interest.
- Stakeholder Acceptance Criteria and Performance Objectives.
- ATM Concept Descriptions

Outputs

- List of Low Level Validation Objectives.

STEP 2 Determine the Experimental Needs

Activity 2.3 Refine Validation Strategy

Description

The purpose of the outline strategy was 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 was likely to be required from the continuing validation process. When the strategy was first produced it was a high (programme) level strategy with high level objectives and brief details on a series of experiments. With a greater understanding of the concept (as should be gained by this stage in the validation process) and a refined set of validation requirements comes the need to revisit and refine the validation strategy.

At this stage in the validation process the team should know the:

- Descriptions of Proposed Concept or Operational Improvement
- Validation Expectations
- Stakeholders Interests
- High Level Validation Objectives
- Low Level Validation Objectives
- Validation Criteria (Stakeholders' Acceptance Criteria)

In projects that are assessing more than one concept there may be the need to combine concepts in experiments. 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 experiments 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.

As before the strategy should also detail who is likely to be carrying out the assessments and where. The strategy should thus detail:

- Who will be carrying out the experiment
- Where it will take place
- When it will take place
- Choice of tool / technique
- Choice of platform (if real time or fast time simulation)
- Which objectives will be addressed in each experiment
- Additional experiments or studies foreseen to address certain key objectives
- Overview of any interactions, relationships or dependencies between planned studies or experiments

All this information together with the refined assessment requirements will allow for a much more detailed validation strategy to be produced. Also, the simple fact that it is closer in time to any planned experiments or studies means that these can be planned with greater certainty.

STEP 2 Determine the Experimental Needs

Activity 2.3 Refine Validation Strategy

Inputs

- Descriptions of Proposed Concept or Operational Improvement
 - Validation Strategy and plan
 - Refined Validation Requirements
 - Low Level Validation Objectives
-

Outputs

- Refined Validation Strategy

STEP 2 Determine the Experimental Needs

Activity 2.4 Identify Indicators and Metrics

Description

As described in Activity 2.3, low level validation objectives should be specific and measurable. Thus a further breakdown of these objectives should identify the specific measures to be taken and for a list of indicators and metrics to be derived.

A metric is a parameter that can be measured directly or can be calculated from several measurements (from MAEVA). An indicator is 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:

Expectations ➔ Lifecycle Phase Objectives ➔ 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 KPA.

Broadly speaking there are two categories of indicators and metrics.

- **'Generic' indicators and metrics** - these indicators and metrics (I&M) are not concept specific. The focus is more on the ATM KPA than on the proposed concepts. I&M such as these can be applied to more than one concept and are particularly useful when comparing results across experiments or concepts. Common examples include ISA, R/T usage and sector throughput. Many lists of I&M currently exist from projects such as TORCH and INTEGRA and 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 I&M 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 I&M 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 experiments 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.

Thought must be given as to how the parameters will be recorded. The techniques available include logging metrics from the simulator platform, questionnaires or individual ISA responses.

Those that can (in theory) be logged by the platform should be listed and will be included in the simulation platform requirements and this is addressed as part of Activity 2.10, Assessment Requirements. If a parameter cannot be directly logged by the simulator alternative means must be used to record the parameter. In such cases tests such as ISA and NASA TLX are among the techniques available.

STEP 2 Determine the Experimental Needs

Activity 2.4 Identify Indicators and Metrics

Accuracy of the parameter will also be a consideration. The most accurate method for capturing parameters is logging them automatically on the simulator platform. The more accurate the method is, the more confidence can be had in the subsequent results.

Inputs

- Low Level Validation Objectives
 - Concept Descriptions
-

Outputs

- List of Indicators and Metrics.
- Datalogging specification (to be integrated into Simulation Platform Requirements).

STEP 2 Determine the Experimental Needs

Activity 2.5 Specify Validation Scenarios

Description

The purpose of this activity is to produce a specification for scenarios that exercise the ATM concept as required by the validation exercise objectives in an operationally realistic manner. This activity is focused on real time and fast time simulations.

Validation Scenarios are used to provoke ATM system performance and behaviour in a simulation setting, thus testing hypotheses, assumptions and expectations. They are based on a set of concept descriptions produced by the Operations Team during concept development.

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 used 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 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. In this way, a validation scenario will test the assumptions in the concept scenarios and thus the concept design.

The validation scenario is that which is actually implemented in a simulation in order to provide robust feedback in terms of whether or not a proposed concept can be implemented in the operational environment. Validation scenarios are actually run in the experiments, 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.

There should be a high level of commonality between concept scenarios and validation scenarios. If the designers describing the concept are not aware of the potential validation scenarios there is a risk that the design will not be prepared for the types of situation against which it will be tested. This will almost inevitably lead to failure at the test stage.

This step is carried out in five phases, as follows:

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

Appendix 2 of the OCVSD [2] provides best practices for the development of scenarios for fast and real time simulations.

STEP 2 Determine the Experimental Needs

Activity 2.5 Specify Validation Scenarios

Inputs

- Operational Concept typical scenarios
 - Description of the ATM Problem and the ATM concept.
 - Low level Validation objectives and metrics.
-

Outputs

- Validation Scenario specification.
- Traffic samples (if required).

STEP 2 Determine the Experimental Needs

Activity 2.6 Produce the Experimental Plan

Description

This activity is a further extension of the Validation Strategy (step 2.4) but this time it will focus on an individual experiment. For each experiment listed in the Validation Strategy a plan should be produced formalising what is said about that experiment in the Validation 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 activity will be an Experimental Plan. This plan will be a major input of several subsequent key documents such as the Analysis Plan and the detailed Experimental Design. It is likely to be done in parallel with the work on Scenario Specifications (Activity 2.7)

For each experiment the plan will have three main areas of focus: Refined Experimental **Strategy**, Experimental **Scope** and Experimental **Planning and Management**.

Refined Experimental Strategy

This part of the document should contain, for this particular experiment, information on:

- Stakeholders and their Acceptance Criteria
- Low Level Validation objectives and KPA
- Choice of Indicators and metrics
- Overview of any interactions, relationships or dependencies between this and other planned studies or experiments

Experimental Scope

This part of the document 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
- Length of Experiment (and thus an indication of likely number of exercises)
- Scenarios

Experimental Planning and Management

This part of the document should contain information on:

- Resources:
 - Manpower required / available
 - Budget required / available
 - Trade off if necessary
- The activities to be undertaken, such as:
 - The tasks that need to be performed
 - The deliverables that will be prepared
- When the activities will be performed:
 - Planning of tasks and meetings in time (visualised in a time line chart or equivalent)
 - Key decision points
 - The milestones in the project, such as, the acceptance of the validation platform, the execution of the exercise and the delivery of the final report
- How the activities are to be undertaken:
 - The approach applied and the method(s), technique(s) and tool(s) used
 - Procedures to ensure quality of the work

STEP 2 Determine the Experimental Needs

Activity 2.6 Produce the Experimental Plan

- Responsibilities in the exercise:
 - The individuals that will undertake the exercise, these people will perform the work and will supervise and observe the exercise runs
 - Input and/or co-operation expected from the stakeholders
- Risk:
 - Risks involved
 - Mitigation or risks
 - Contingency Plans.

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 activity may overlap with the activities on the refined validation strategy and the scenario specifications.

Inputs

- Refined Validation Strategy.
- Validation Scenario Specification (in parallel, this is likely to be a two-way interaction).

Output

- Experimental Plan

STEP 2 Determine the Experimental Needs

Activity 2.7 Produce Analysis Plan

Description

The Experimental Plan set out the validation designer's plans with regard to what kind of experiment will be conducted. The next stage is to produce an Analysis Plan for that experiment. The Analysis Plan uses as input the validation aims and objectives, the chosen indicators and metrics, and the Experimental Plan.

The aim of the Analysis Plan is to come up with a plan which states:

- Low Level Validation Objectives
- Data collection methods
- Training requirements
- Analysis methods
- Statistical hypothesis
- Operational and Statistical significance
- Outline reporting plans

For some techniques there is additional information required and this is given below.

Literature Search

A statement should be included on what information is to be gathered and how it is to be analysed. This will include stating the criteria for determining the confidence level in data from the different sources.

The number of documents to be analysed will be determined by the level of confidence required from the study, the availability of suitable documents and the timescales and budget available for the exercise. A small number of high level documents may be analysed quickly, but the level of confidence in the conclusions will be low. In contrast, if there are a large number of detailed documents that are directly relevant to the aims of the validation exercise, the level of confidence in the conclusions will be higher. If many potentially suitable documents are found, the selection constraints may be tightened to reduce the number to be read (and stay within budget/time constraints). The final selection of documents will depend ultimately on the availability of suitable documents.

Judgemental techniques

A statement should be included on the focus for discussions, what will be recorded and how the experts' subjective opinions will be analysed. The recorded data will be qualitative and criteria should be provided on how opinions should be collated and presented for any feedback sessions.

Briefing materials describing the aims of the exercise, the ATM problem and the operational concept must be produced and sent out to the participants at an adequate time before the experiment. The briefing material may also provide information on the conduct of the exercise and any particular scenarios to be considered.

The preparation of the facility to be used may involve training the validation team members who will be facilitating and leading the panel(s). It is very important that discussions are controlled sensitively to ensure they remain productive and reach conclusions if appropriate. Some approaches may require questionnaires or structured forms to be prepared so that the views and discussion are recorded efficiently in relation to the validation aims and objectives. Facilities such as video cameras or tape recorders may be required and need to be set up in such a way that they do not interfere with the proceedings.

STEP 2 Determine the Experimental Needs

Activity 2.7 Produce Analysis Plan

Fast-time techniques

A plan is required for each experiment 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 low-level validation objective or area of interest. At this stage, the final decisions on which measurements will be taken (drafted in previous activities of Step 2 Production of Experimental Plan) should be taken. A number of measurements could contribute to more than one objective. The validation objectives, identified in activity 2.3 should be stated under the heading of the related high-level validation objective or research aim. The hypotheses should also be noted along with a description of the measurements that are to be recorded.

Operational and statistical significance levels should be stated here, with an explanation of the reasons why these levels were chosen. The section regarding selection of analytical approach will describe the structure of the analysis process. It is assumed that the team conducting the trial has experience of data analysis methods.

Real-time techniques

The issues described for fast-time techniques also apply to real-time techniques. In addition to these, two further issues that should be considered are:

- the requirements placed on controllers;
- training issues;

These issues are now described:

- The requirements placed on the controllers will differ depending on:
 - the validation aims and objectives;
 - the type of trial;
 - the length of the trial;
 - the number of sectors.
- While it is possible to make requests there are usually only a limited number of available controllers and those available cannot be guaranteed to meet all the requirements. The controllers and their qualities will impact on the analysis. Where requirements are not met it is necessary to identify any steps that could be taken to ensure that the aims of the trial are not comprised.
- A detailed description of the training issues should be given in the training issues section of the plan. The training issues will vary depending on:
 - whether controllers meet the requirements set out in the controller requirements section of the plan;
 - the language the training is to be conducted in;
 - the understanding of the concept by the controller;
 - the scale of the difference between current day systems and the advanced system;
 - the level of knowledge of the current and advanced systems required;
 - familiarity with the simulation environment;
 - the aims and objectives of the trial.
- It is likely that the training will not be sufficient for controllers to have learnt everything there is to know about a system before measurements begin to be taken. It is further expected that the controllers will become familiar with the traffic samples, although the level of familiarity can be minimised by careful experimental design. Learning effects should therefore be considered during the analysis. The amount of time dedicated specifically to training during the trial should be minimised. As far as possible, training should be undertaken a few weeks prior to the trial, with some time spent during the trial to refresh the controllers' memory. For example in a two-week trial approximately 2 days should be dedicated to reinforcing the previous training.

STEP 2 Determine the Experimental Needs

Activity 2.7 Produce Analysis Plan

- In a trial where a significant amount of training is necessary it is prudent to produce a training plan. The first stage in developing a training plan is to consider the objectives of the training. It is unlikely that the controllers will be familiar with everything before the start of the validation exercise, however, it is useful to define exactly what knowledge each controller should have. This will enable decisions to be made on the best way in which to train the controllers and the extent to which the training has achieved its aim will also be clear.

Shadow Mode Trials

Many of the issues described for real-time techniques also apply to shadow mode trials. In addition to these, two further issues that should be considered are:

- Type of Shadow mode - 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.

Complimentary Assessment Techniques

The Analysis plan should also contain information on other data collection methods or analysis methods to be used in the experiment. Examples here are Instantaneous Self Assessment (ISA), Task Load Index (TLX), questionnaires, debriefs, pair wise comparison, triangulation etc.

Outline reporting plans

During the stakeholder analysis the stakeholders will have informed the validation designers what their information needs are. These will drive the format of the output produced and this format should be laid down here. The use of tools such as the VDR (ref. 5) for reporting should also be explained here.

Inputs

- Experimental Plan
- Low Level Validation Objectives
- List of Indicators and Metrics
- Validation scenario specification

Output

- Analysis Plan

STEP 2 Determine the Experimental Needs

Activity 2.8 Produce Detailed Experimental Design

Description

The aim of experimental design is to provide a 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. Robustness can be compromised both if the measurements made are not clearly related to the factors of interest and if the number of measurements is insufficient and representative of the future use of the system. These aspects must be addressed correctly in the experimental design so that clean and robust measurements are used to reach accurate and sound conclusions.

The method used for detailed experimental design will vary according to the type of experiment, 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 inputs to this sub-activity are illustrated in Figure 8:

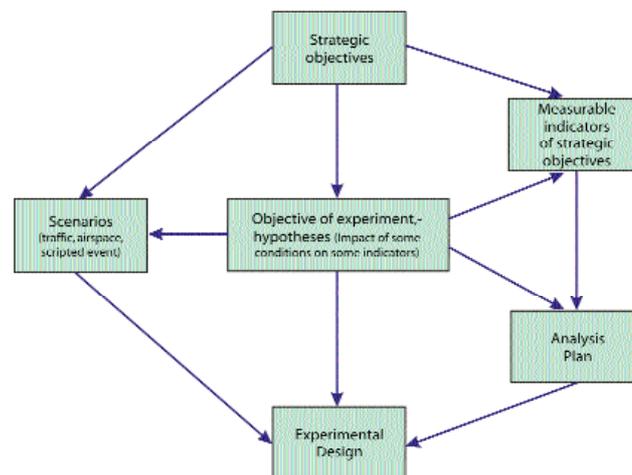


Figure 8: Inputs into Experimental Design

Two questions that must be addressed in this activity are how to select scenarios and resources and how to best use them to meet objectives. The choices to be made include the validation technique, the platform, the number of scenarios (encompassing geographic area, traffic level, etc.), the number of participants involved and any other aspect that may have an impact on the achievement of the objectives in terms of budget and time. These choices differ depending on the technique used. The factors that need to be specified for each type of validation technique can be summarised as follows:

- Judgemental techniques: the selection of the experts (including number, experience and duration of involvement) and the design of the material to be used by the experts.
- Fast-time simulation: the time allocated, the modelling tool that will be used, the number of geographic areas to be simulated, the number and type of traffic samples, the reference baseline used and the workload calibration (if workload is one of the variable to be measured).
- Real-time simulations: the size of the exercise in terms of the number of participants; the number of runs; the number, size and type of the geographic areas to be simulated; the number of traffic samples; the type of participants and the manner in which they are to be prepared; the reference baseline used; and the content and degree of realism of the scenarios.

STEP 2 Determine the Experimental Needs

Activity 2.8 Produce Detailed Experimental Design

- Shadow mode: the manner in which the participants are to be prepared; the length, time and conditions of the trials; the type of traffic under shadow-mode control; and the possible installation of new equipment in aircraft.
- Operational trials: the scale of the trial in terms of space, the scale of the trial in terms of the flights concerned, the conditions and length of the trial, the preparation of participants.

The Experimental Design should contain 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.
- A description of the chosen analysis methods
For real time and fast time simulations:
 - A statement of the length of the simulation
 - A statement of the number of runs (measured and training) in the simulation
 - A description of the factors being experimented
 - A description of the scenarios to be used during the experiment
 - A timetable for the planned experiment

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.

Inputs

- Descriptions of the ATM Problem and ATM Concept.
- Validation Strategy
- Analysis Plan
- Validation expectations, objectives and criteria.

Output

- Detailed Experimental Design
- Revisions to Experimental Plan

STEP 2 Determine the Experimental Needs

Activity 2.9 Identify Assessment Requirements

Description

Although this appears as the penultimate activity in this step, in reality it is likely to be run in parallel with activities 2.5 -2.9.

This activity involves reviewing all the various plans and needs that have been identified so far and drawing up a list of requirements. This list should answer the question “What do we need to do in order to get the experiments to run?” The purpose of this is to ensure that all aspects of the concept can be tested and that all the required information can be gathered using the chosen tool or technique and analysis methods.

Probably the most important set of requirements, especially with Real Time simulation platforms, are the **platform requirements**. In order to provide total functionality for the concept or total coverage of the indicators and metrics the platform will need to be adapted (where feasible). Careful choice of tools or techniques should minimise gaps and the use of more than one platform or adapting existing platforms will also help. However, failure to cover these gaps or provide requirements will mean decisions will have to be made on the quality of results. 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. Any requirements made on the simulator platform should be added to the initial simulator platform requirements to produce a refined Simulator Validation Requirements Specification. These requirements may need to be updated regularly as the validation design develops. 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.

A further aspect of the validation design that has an impact on the platform requirements is the choice of validation scenarios. Some scenarios chosen, and in particular non-normal events, may highlight the need for very specific events. The simulator must be able to cope with these **validation scenario requirements** in order to run the validation scenarios and test the associated objectives.

The analysis methods outlined in the Analysis Plan will have **analysis requirements**. They will highlight where additional complimentary techniques may be required to gather certain information (e.g. the use of NASA TLX or PUMA during a real time simulation). 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.

Of course, without being able to collect the required indicators and metrics, the analysis can only take place on a qualitative level. Thus the assessment should enable the capture of all the required indicators and metrics. 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. To do so it is common for the project team to provide the platform team with a list of **datalogging requirements**. This details all the parameters expected to be logged by the simulator and a common format for the log message. By doing this the project 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.

STEP 2 Determine the Experimental Needs

Activity 2.9 Identify Assessment Requirements

Inputs

- Description of the ATM problem and proposed concept.
 - Validation Strategy
 - Validation Scenarios
 - List of Indicators and metrics
 - Analysis Plan
-

Outputs

- Set of Assessment Requirements
- Set of datalogging requirements

STEP 2 Determine the Experimental Needs

Activity 2.10 Prepare the Platform or Facility

Description

The description of this activity will focus exclusively on fast-time and real-time techniques. It needs to be carried out according to the schedule as set up in step 2.6 "Experimental Plan". It could proceed in parallel to steps 2.7 – 2.10.

Fast-time techniques

The aim of preparing the platform is to configure it to represent the ATM problem, as expressed through the scenarios, and the operational concept. The elements of the platform that need to be considered are shown in Figure 9. The core of the platform consists of the simulator itself, but it cannot be considered in isolation from the input files, and the requirements of analysis and data presentation.

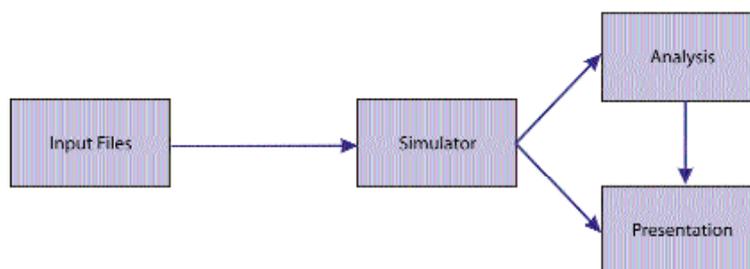


Figure 9: Elements of the Simulation Platform

These elements are now considered:

- A set of input data files will be derived from the scenario description. It is important to know how much work this will involve. Typically this may include traffic sample extraction and growth, or the creation of an airport ground layout.
- The preparation of the simulator will be driven by the scope of required modelling. This will be driven by the validation objectives. For example, it is unlikely that an en-route study would need aircraft ground movement to be modelled in detail. Again, it will be important to know to what extent new software is required to reflect new functions relating to the ATM concept, and what the implied time scales are.
- 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.
- Presentation requirements may have an impact on both the analysis tools and the choice of simulator. They should take into account both the testing/validation stage of the simulation, where a particular form of output associated with the functioning of the operational concept may be of use, and the analyses themselves. Different types of presentation may be required for different parties.

Real-time techniques

The platform(s)/tool(s) must resemble the real-life situation as closely as necessary; they may therefore need to be adapted by adding functionality specific to the operational concept considered. If for example a free flight concept is examined, a CDTI (Cockpit Display of Traffic Information) needs to be implemented in the cockpit of the aircraft involved. Other preparations may include for example the airspace structure and measurement data storage.

Also preparations need to be made for the measurements and for collecting feedback from the exercise participants. This may comprise of the selection and set-up of measuring equipment like ISA boxes and the development of questionnaires. Observations are recorded using observers during the measured runs, and the validation staff, who will be acting as observers, will need to be trained.

STEP 2 Determine the Experimental Needs

Activity 2.10 Prepare the Platform or Facility

Inputs

- Unconfigured Platform.
 - Assessment Requirements
 - Detailed Experimental Design.
-

Output

- Configured platform, including input files and additional functionality provided for the model.

STEP 2 Determine the Experimental Needs

Activity 2.11 Conduct Pre-exercise Testing and Training

Description

The description of this sub-activity will focus exclusively on fast-time and real-time techniques.

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. 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 model developed.

Real-time techniques

The real-time platform is tested through a shakedown trial. This is a trial about one week, it may involve the use of operational participants. There will be no plans to make any measurements for analysis.

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

- Forms a representative model of the real world to be validated;
- Provides a robust 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. 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.

Inputs

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

Output

- Tested validation platform ready for the validation exercise runs to be performed.

STEP 3 Conduct Experiment*

Activity 3.1 Conduct the Validation Experiment

* This step taken directly from the MAEVA VGH

Description

The purpose of this step is to execute the validation exercise, as specified in the detailed experimental design, on the validation platform in order to obtain a set of measurements, replies and other data that will be analysed in Step 4.

At the end of Step 2, everything has been left ready for performance of 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 different types of data that may be collected during the run(s), because the type of data determines the type of analysis that will be able to 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.

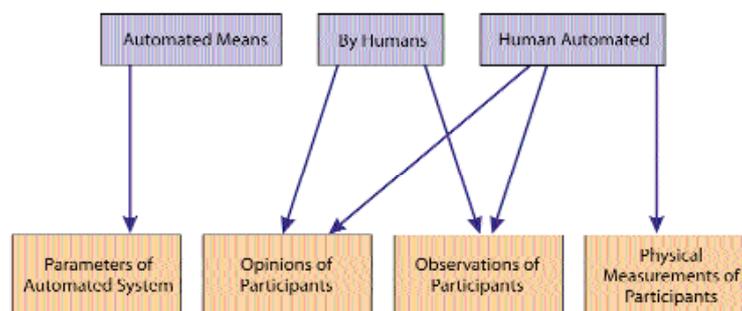
The following data types are, in general, applicable to ATM validation exercises (and simulations in particular):

- 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 10 below:

Figure 10 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



STEP 3 Conduct Experiment

Activity 3.1 Conduct the Validation Experiment

Figure 10: 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 data 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 the one is used as an input of the other.

The exercise runs will involve eliciting and recording the opinions from the expert panel members; these 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 post 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 recordings.

Fast-Time Techniques

Before the execution of the validation exercise run(s) starts, the validation team will have a clear plan in place. This will provide a detailed specification of the configuration of the validation 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 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 step, as it will be very dependent on the particular platform being used.

Where the validation platform is a detailed ATM simulator, the process can be automated. 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 over a weekend.

STEP 3 Conduct Experiment

Activity 3.1 Conduct the Validation Experiment

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 plan 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.

Inputs

- Detailed Experimental Design
- Validation Scenarios
- Validation Plan
- Configured and tested Validation Platform.

Output

- "Raw" data, in a form suitable for analysis, obtained from the measurements and questionnaires used during the validation exercise run(s).
- Logs of the system parameters recording the status of validation platform.

STEP 3 Conduct Experiment

Activity 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 experiment, 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 may be of vital importance to further development and should not be ignored or considered as a nuisance.

Any unexpected results should be analysed 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 experiment. Once the impact of any unexpected results has been analysed, decisions can be taken as to whether any modifications to the validation strategy or the validation analysis are necessary.

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 inducing:

- 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

- Conduct Validation Experiment

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*

Activity 4.1 Perform the Analysis Specified in the Analysis Plan

* This step taken directly from the MAEVA VGH

Description

The purpose of this activity is to perform the methods of analysis as specified in the Analysis Plan (and incorporating findings of step 3.2 if necessary) on the measurements generated in Step 3, in preparation for the production of the analysis contributions in Activity 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 conclusion, often with an associated 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 Normal 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

Activity 4.1 Perform the Analysis Specified in the Analysis Plan

- 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 plan that was produced in the second step. The types of analysis that are feasible will have been determined by the original experimental 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 if the simulation is not realistic. Also the affect of any limitations imposed by the platform in the scenarios or operational concept modelled need to be considered.

STEP 4 Determine the Results

Activity 4.1 Perform the Analysis Specified in the Analysis Plan

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;
 - Poorly controlled conditions.
- Since ATM actors are involved, the amount of subjective data relative to objective data is probably higher. Moreover these subjective data are usually from a small number of individuals; it should be considered whether they are representing the views of the whole ATM community. Both will affect the conclusions that can be drawn, and especially the level of confidence applied to its operational significance.

Inputs

- Measurements/Data collected in Step 3.
- Analysis Plan

Outputs

- Refined/ordered data ready for analysis.

STEP 4 Determine the Results

Activity 4.2 Prepare Analysis Contributions

Description

The results generated in Activity 4.1 can be compared to the original validation criteria set out in Activity 2.3. This enables the validation team to see which hypothesis has been met and also what the operational significance of the results could be. 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. This comparison to validation criteria and operational context determines which of the results are meaningful.

A set of analysis contributions can be made for each of the KPA. 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 activity 2.5 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. 5)

At this stage it is not the job of the validation team to draw conclusions about the success or failure of the operational concept. The most they can do is objectively state the results as they see them and say how this performance relates to the original criteria set at the beginning of the validation activity.

Inputs

- Validation Criteria from Activity 2.1
- Indicators and Metrics (schematic) from Activity 2.5
- Results from Activity 4.1

Outputs

- Analysis contributions

STEP 4 Determine the Results

Activity 4.3 Prepare and Review Validation Report

Description

The validation report is the main output from the validation activity and should contain a synthesis of the results from all the experiments.

The validation report should contain information on:

- Review and Introduction
 - Project Background
 - Low Level Validation objectives
 - Review of experiment
 - Analysis methodology
 - Any problems encountered in the validation activity
- Results and Discussions
 - Generally only high level meaningful results
- 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.
- Input of results into the VDR.

Inputs

- Analysis contributions

Outputs

- Validation Report
- Validation results in the VDR.

STEP 5 Disseminate Information to Stakeholders

Activity 5.1 Disseminate information for stakeholders and decision makers review

Description

Throughout the validation process information from the stakeholders and decision makers has been used. It is at the end of a development lifecycle phase that they are given consolidated information about the experiments during the completed lifecycle phase. The object of the validation process is to provide the decision makers with enough useful information to enable them to make decisions about the further lifecycles of the proposed operational concept.

The bulk of the information you will give them is contained in the main deliverable – the validation report. The contents and aim of this report is described in the previous step. However, there are other points to consider when providing information to the decision makers for review:

- This is the first explicit deliverable containing the information the customer needs. However, throughout the validation process, from step 0 through to now, you will have been providing them with information whenever relevant and necessary.
- The report typically takes several months after the last experiment of a lifecycle phase to compile. This is obviously too long for the customer to wait. In the meantime, as soon as some preliminary results are known, 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 and may change as analysis continues.
- Any result should not be reported to the customer until the validation team has confidence in the findings. The validation team must be able to confidently back up any findings they present. The traceability exercised in the Analysis Contributions will be useful here.
- The validation team required a lot of stakeholder input in the early stages of the validation process and it is at this stage that the validation team should make itself available to answer the customers' questions.
- Different stakeholders will have a different idea of what are the key results. It is for this reason that the validation team must make all information available to those involved. The Analysis Contributions can be used here in lieu of the main report as these should have information on all the KPI assessed during the experiment.
- The report is the product the customers are 'buying'. It must provide them with enough useful information to enable them to make a fair assessment of the system. If it cannot (perhaps due to various reasons encountered during the experiment) this must be justified.
- The validation team should not try to influence the stakeholders decisions or let the stakeholders influence their findings. They must remain completely objective in their presentation of the results.

Inputs

- Analysis Contributions
- Validation Report

Outputs

- Information delivered to Stakeholders
- Stakeholder review of results

STEP 5 Disseminate Information to Stakeholders

Activity 5.2 Draw Conclusions and decide on Actions / Feedback

Description

Throughout this methodology a major principle has been that it is not up to the validation team to draw conclusions about the success or failure of the concept or project. That task is left to the stakeholders. Using the information supplied in Activity 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.

Thus, although this is the final validation activity in programme, the final output of this can be one of the first inputs into a new programme.

Inputs

- Analysis Contributions
- Validation Report
- Interim presentations, reports and information.

Outputs

- Conclusions and actions. Feedback and modification to validation strategy.

Glossary

The following definitions have been taken from the MAEVA glossary except where noted

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.

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.

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

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.

HOLISTIC: Emphasising the importance of the whole and the interdependence of its parts; Concerned with wholes rather than analysis or separation into parts.

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.

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.

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.

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

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

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.

SCENARIO: Representation of an operational situation in which an ATM operational concept is validated within validation exercises, to enable the measurement and characterisation of the operational concept's performance. Scenario descriptions should cover at least the location, timeframe, events and ATM environment.

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.

SIMULATION EFFECT: An effect found in simulations whereby results can be distorted through the controllers experimenting with the new system in order to find out the best method of use or to test the 'limits' of the concept.

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.

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.

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

VALIDATION AIM: A statement of the proposed level, detail and outcome of the validation activity. A clear outline of what is to be expected from the validation process.

VALIDATION CRITERIA: Hypothesis and rules used to determine whether a system has been validated.

VALIDATION OBJECTIVE: A statement of what the project team will work towards to achieve the aim. A formulation of the validation aim in measurable factors.

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 PLATFORM 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.

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 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.

List of Acronyms

ACC	Area Control Centre
AMOC	ATFM Modelling Capability
ATM	Air Traffic Management
AP5	FAA/EUROCONTROL Joint Action Plan 5 Validation
CAATS	EC 6th Framework project – Cooperative Approach to Air Traffic Services
COSAAC	Common Simulator to Assess ATMF Concepts
EC	European Commission
ECAC	European Civil Aviation Conference
EVAS	EATMS Validation Strategy
FAA	Federal Aviation Authority
FAP	Future ATM Profile
GTG	GATE TO GATE
HMI	Human Machine Interface
JPB	Joint Programme Board
ISA	Instantaneous Self-Assessment
KPA	Key Performance Area
KPI	Key Performance Indicator
MAEVA	Master ATM European validation Plan
OC	Operational Concept
OCSV	Operational Concept Strategy Validation Document (AP5)
OI	Operational Improvement
PRC	Performance Review Commission
RAMS	Reorganised ATC Mathematical Simulator
SRC	Safety Regulation Commission
STATFOR	Specialist Panel on Air Traffic Statistics & Forecasts
TAAM	Total Airspace & Airport Modeller
TC	Terminal Control
TMA	Traffic Manoeuvring Area
TRL	Technology Readiness Level
TLX	Task Load Index (NASA)
VDR	Validation Data Repository

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