FAA/EUROCONTROL COOPERATIVE R&D

ACTION PLAN 5: Validation and Verification Strategy

Results and Conclusions from Preliminary Analysis of

Requirements Role in Verification Process

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Executive Summary

In the year 2000, the FAA/EUROCONTROL Research and Development (R&D) Committee requested that Action Plan 5 (AP5) participants create, if possible, a common validation strategy. The Operational Concept Validation Strategy Document (OCVSD) addressed this request and established a common understanding of the context, purpose, and scope of validation. In 2007, the OCVSD was updated to include new material that provides 1) insight into the relationship between concept validation and requirements, 2) a discussion on the role of operational scenarios and 3) a refined methodology that is traceable, transparent and accessible. While the current version of the OCVSD focuses on the definition and scope of validation within the concept development lifecycle AP5 participants recognized that there is insufficient guidance in the area of verification and began a series of working meetings to clarify the definition and role of verification within the operational concept lifecycle.

In order to present a verification strategy, it is necessary to develop a common understanding of the role of requirements in the R&D process including a standard definition of requirements, which phase of the lifecycle they apply to, how they are used and who establishes them. In an effort to gauge current practices within the R&D community, AP5 participants developed and administered a survey to query practitioners from both the United States and Europe regarding current R&D practices in the areas of requirements development and management including: requirements collection, requirements categorization, and requirements usage. By examining projects within both communities, we attempted to document consistency in terms of requirements development and management that bears a concept verification strategy and supports the development of adequate and reliable systems. This document serves to summarize the progress AP5 has made in expanding the definition and role of verification within context of concept development and to build on what has been learned through recommendations and next steps.

1 INTRODUCTION

1.1 Background

The purpose of Action Plan 5 (AP5) is to develop a common approach (i.e., strategy) to the validation and verification of operational concepts for air traffic management (ATM). Currently, the principal output of AP5 is the Operational Concept Validation Strategy Document (OCVSD), which was extensively updated in 2007 to take into account lessons learned during the build up to Next Generation Air Transportation System (NextGen) and Single European Sky ATM Research (SESAR). While this current version of the OCVSD focuses on the definition and scope of validation within the concept development lifecycle AP5 participants recognized that there is insufficient guidance in the area of verification and began a series of working meetings to clarify the definition and role of verification within the operational concept lifecycle. To that end, AP5 members have decided to focus temporarily on requirements management by exploring the relationship between the requirements developed as a result of the validation process and the requirements used to ensure an operational concept is properly developed.

1.2 Purpose

The AP5 working group acknowledges that verification is closely linked to the development and management of requirements. The recent activities undertaken by the AP5 team represent an initial attempt at identifying the role of requirements during the various phases of the operational concept lifecycle with the objective of developing a verification strategy that will establish a common understanding of the context, purpose and scope of verification. The purpose of this paper is two-fold:

1) document the verification activities that have occurred between April 2007 and May 2008 and

2) synthesize the findings into a cohesive report as a means of generating discussion within the R&D community.

2 OVERVIEW OF AP5 VERIFICATION ACTIVITIES

The pursuit of a verification strategy was set in motion at a working meeting in April of 2007. Meeting attendees concluded that in order to complete a Verification Strategy it is necessary to first, have a common understanding of the role of requirements in the Concept Lifecycle process and second, have a consistent and common understanding of the terminology (e.g., Operational Concept, Concept of Operations, Concept of Use, Operational Services and Environment Description (OSED) ED78A. As a first step, the AP5 team worked to establish a consistent and agreed upon definition for *requirement* that identifies which phase of the lifecycle requirements apply to, how they are used and by whom (roles). The team agreed to initiate two tasks:

1) a literature review, and
2) a survey of R&D and acquisition experts regarding their use of the term requirements.

In response to the first task (literature review), the Nationaal Lucht- en Ruimtevaartlaboratorium (NLR) conducted a study of terminology and standards. The draft report was presented and discussed at the November 2007 working meeting. The report was finalized after team members' comments were vetted and incorporated. A summary of the results are in Section 3.

Taking into account the results of the above study, AP5 members developed a questionnaire to query subject matter experts (SMEs) and practitioners from both the United States and Europe regarding current R&D practices in the areas of requirements development and management including: requirements collection, requirements categorization, and requirements usage. By examining projects within both communities, the goal of the exercise was to establish consistency in terms of requirements development and management. AP5 team members contacted several projects and received responses from twelve of them. The results were presented and discussed at the May 2008 working meeting. A summary of the results can be found in Section 4.

A collective of the findings is presented in Section 5 and recommendations for further work (e.g., Verification Strategy Strawman) are in Section 6.

3 REVIEW OF TERMINOLOGY AND STANDARDS

Currently, many terms relating to operational concept validation and the associated requirements gathering and management processes are used with inconsistent interpretations. This section summarizes the analysis of terminology performed by NLR as part of a study they conducted on the role of requirements during the different phases of the operational concept lifecycle. The review of the terms listed below and the recommendation for their use is based on well-known resources including - but not limited to - the EATMP glossary of terms and the FAA Acquisition System Toolset (FAST). The complete study, the "Role of Requirements in ATM Operational Concept Validation" (RORI-OCV) can be found in Ref. [5].

3.1 Terminology

The subsequent paragraphs document the use of the following terminology:

- Operational Concept
- Concept of Operations
- Concept of Use
- Operational Procedures
- Operational Requirements
- User Requirements
- Functional and Non-functional Requirements
- Technical or Technology Requirements
- System Requirements
- System Specifications

One of the main outcomes of the study on terminology is that there are many terms for similar, but not always identical, artifacts or activities that are often tailored to a specific problem domain or organization. Thus, in most cases, it is necessary to ask the specific user of such a term or the related organization for a clear definition. Nevertheless, the survey of terminology attempted to concentrate on the commonalities among definitions and, therefore, a number of general conclusions about the use of concept and requirement related terms can be drawn.

The definition of an operational concept is useful to distinguish between high-level concept documents that give a high-level description of ATM services and environment, and Concepts of Operation or Use, that provide more detail on user needs and requirements - the way that the system parts are operated, organizational issues, functions and processes, interactions and information flows, involved actors and their roles and responsibilities. Operational procedures are defined to consist of abovementioned rules, regulations, processes and working practices.

Requirement-related definitions describe a basic distinction between stakeholder needs (sometimes also called user requirements) and requirements. Stakeholder needs may be inconsistent, technically or financially impossible, and may contain implementation details, design decisions or any other kind of statement on the system or function to be developed. Stakeholder needs are input to the requirements analysis process. They are sometimes referred to as 'raw requirements' and are often documented in a Concept of Operations (ConOps) or a similar document (OCD, OSED, ConUse).

The first activity in a requirements analysis process is to transform the identified needs into requirements. These requirements must be clear and consistent, without unnecessarily limiting the possible set of design solutions. The complete set of (validated) requirements is the basic part of the system or software specification, and is usually documented in a system or software requirements specification document. The complete specification should also contain information on functional aspects, design, behavior, and other characteristics of the system or software together with the necessary tests that have to be carried out for verification of the requirements.

Requirements are often divided in categories based on system-external distinguishable properties, such as origin (user requirements, environment requirements, interface requirements, regulatory requirements etc.), or based on system-internal distinguishable properties, such as functional/non-functional requirements, performance requirements, quality requirements, security requirements etc.

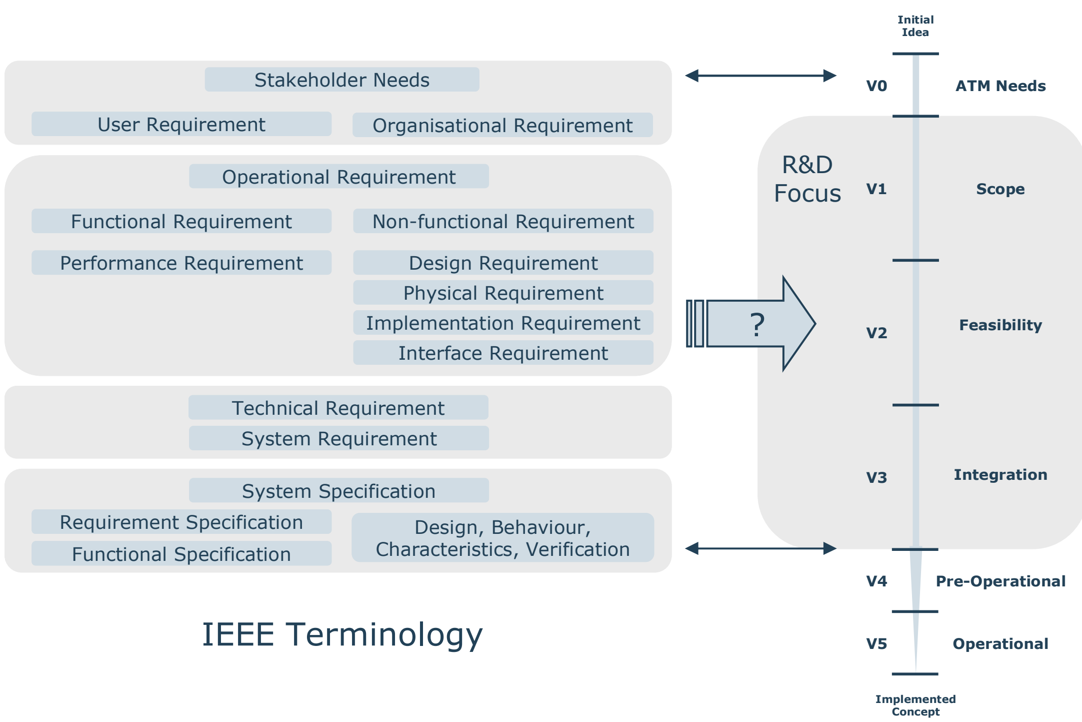

Figure 1: Requirements Terminology

Although the specifications available at the end of phase V3 (see Figure 1) should consolidate the requirements and the validation results, it is not quite clear what the required level of detail actually is. After all, there are still research specifications that might or might not be in line with technology development. Therefore, an additional aspect in the R&D phases is the relationship between customers and suppliers of the technology concerned and the kind of technology being developed (component, sub-system, system, system of systems, enabler etc.).

4 RESULTS: REQUIREMENTS MANAGEMENT PRACTICES QUESTIONNAIRE

4.1 Methodology

The requirements questionnaire was distributed within NASA, FAA, AENA, NLR, DFS, and EUROCONTROL to 17 subject matter experts (SMEs) experienced in validation research and human-in-the-loop (HITL) exercises. The questionnaire was administered in one of several ways: face-to-face, telephone interviews or via email. Data from the 11-question survey were collected either by an AP5 participant or practitioner self-response. Practitioners were instructed to respond to the survey questions based on previous or current project experience they had participated within the past five years.

4.2 Data Collection

Of the 17 questionnaires distributed, 13 questionnaires were completed and available for review at the April 2008 working meeting. Respondents were given approximately four weeks to respond to the questionnaire. In an effort to clarify and answer questions about the survey, the FAA held two teleconferences (March 7 and March 19, 2008) and supported several discussions.

4.3 Projects Surveyed

The following projects[1] contributed to the survey of requirements management practices. A summary of the results for each project is contained in Appendix A.

- Airport layout for O'Hare modernization
- Big Airspace
- iTEC
- AMAN at Munich Airport
- EMMA2
- Self Check In for an Airline (CKI)
- European AIS Database (EAD)
- First ATC Support Tool Implementation (FASTI)
- Continental RVSM Europe
- European Initiative: Safety Net Development
- Statistical Analysis System (STANLY)
- Project X
- Project Y

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[1] Two of the thirteen returned questionnaires did not specify a project name. All other data from these surveys were captured and analyzed.

4.4 Classification of Approaches

Based on the survey responses, three categories were developed that describe practitioner approaches to capturing and managing requirements:

- **Site specific:** Operational Concept / Requirements that focus on a specific site and build on specific circumstances at that site such as check-in terminals for a specific airline, arrival manager or layout for a specific airport. These projects were ALP, AMAN, CKI, and STANLY.
- **Generic:** Operational Concept / Requirements are universal such as tools, safety nets, and procedures. These projects were iTEC, FASTI, EMMA2, Big Airspace and Safety Nets.
- **Hybrid:** Typically the implementation of generic standards (e.g. from ICAO) to specific locations. These projects were EAD and European RVSM.

Table 1 summarizes the findings per approach.

Table 1: Classification of Requirement Development Approaches

<table>
<tr><th>Site Specific</th><th>Generic</th><th>Hybrid</th></tr>
<tr><td colspan="3">New Operational Concepts / Requirements are typically drawn up by leading experts alone or by group of experts in ad hoc task forces. They are documented in some form which deems to be appropriate to them. Initially they typically do not use established standards. Initial Operational Concepts / Requirements tend to be naïve and driven by some sort of enthusiasm.</td></tr>
<tr><td>
Aiming at a specific problem and short-term (~2 years) solution. Generalization out of scope.
Local expertise and future users fully involved.
Preferred techniques: “Operational prototype” or high fidelity simulation, thus most relevant reality check.
Highly iterative, learning by doing approach.
The initial “naïve” approach is iteratively and incrementally further developed.
Really achievable performances of technical enablers (e.g. accuracy, quality, availability of data in the existing environment) may have a substantially degrading impact on a theoretically desirable concept and require new approaches.
Highly informal.
Requirements identified and documented (if at all) after the experiments, only to a minimum extend before the experiments and hidden by technical staff.
Site specific developments are
</td><td>
Aiming at global applicability.
Typically with a longer development time horizon. Could be 10 – 20 years from first identification to initial implementations.
How to do a reality check without having a specific environment? This is initially typically done by experts in some form of structured task forces. Use cases and scenarios turned out being useful.
Maturing of concepts through experiments using models and simulations is necessary. In particular, in later phases, shadow mode trials at selected typical sites turned out to be important reality checks - the documentation becomes more formal. In a final state, public (e.g. military or EUROCAE) or company specific standards are used more frequently. Formal processes ensuring the involvement of all necessary expertise in reviews are set up. Mostly they allow for number of iterations.
An issue is the degree of detail of the final requirements. In
</td><td>
Operational Requirements available and not questioned (typically ICAO Standards).
Operational Requirements may be supplemented by guidelines to implement them.
More focused on organizational and project management issues.
</td></tr>
</table>

mostly done by a strong internal IT department or with involvements of an industrial service provider.	some cases it is more useful to stay on the level "guidelines", giving the local organizations (in Europe) some room to adapt to their local conditions. • Generic developments are typically carried out in the "classical" R&D environment, making the transfer to industry for final implementation an issue.	

There is certainly interplay between generic and site specific approaches. Site specific approaches may exploit results from generic developments. This suggests that a generic approach is beneficial in the early development phases of V1 (Scope) and V2 (Feasibility). However, once a certain maturity is reached, it may be useful to reduce the scope of the development to the needs of a specific site.

Economies of scale benefits that can be achieved through a generic approach are limited in the ATM area because of the finite number of sites. This is similar to the experiences in the software development environment as illustrated below in Table 2.

Table 2: Experiences in Software Development

In software development there are the following approaches (see Ref. [2]):

- "Informal Development": Fast and focused, little or no formal documentation or tests.
- "Tailored Formal Development": Formal and documented process, fully documented and verified, but site specific.
- "Formal Product Development": As Tailored Formal but additionally configurable to several sites.

Informal Development is fastest and cheapest but certainly implies:

- Involves safety risks
- There are additional risks for future further development

Tailored Formal avoids the risks above but its reuse is limited:

- Less efficient and economical particularly if certification is required

Formal Product more expensive than Tailored Formal:

- Through reuse, it allows for an economy of scale effect

5 SUMMARY OF FINDINGS

The following paragraphs reflect the analysis of the AP5 working team based on the thirteen responses to the Requirements Questionnaire. Our premise is that an organized and structured approach to validating and verifying operational concepts is essential for researching and developing new ATM systems. The AP5 work group recognizes that verification is closely linked to the development and management of requirements, and that the identification of requirements during the operational concept lifecycle process is critical to building an adequate and reliable system. Thus, in analyzing the questionnaires we concluded that there are limited commonalities among the projects represented with respect to identifying, managing, and documenting operational concept requirements. Most projects surveyed involved specific processes to develop, capture and analyze/manage requirements; but in general, there are broad differences to managing requirements. As noted in the respondent comments, customers often had a vague idea of what they wanted (objective) and often became more educated throughout the requirements process and conversations/meetings with subject matter experts. It was also noted that not all projects required validation or production of a prototype to verify requirements against expected results especially when national standards such as ICAO were incorporated during development of the system. Half of the projects followed a formal process to capture and document requirements, and most did not include verification of the developed system. Those that did include a formal process for capturing requirements participated in workshops with stakeholders, customers and users.

Many of the projects did not identify formal requirements documentation which raises questions as to, how requirements should be clearly communicated/documented and who should be included in identifying/gathering them (customers, stakeholders, etc.)? However, there was agreement that requirements engineering must include the following:

- Identifying the initial problem
- Refining initial problem
- Capturing requirements
- Conducting customer/stakeholder workshops to formally obtain expectations and attempt to derive/determine requirements
- Verifying the new system with the stated requirements to confirm whether the stated requirement has or has not been met
- Requiring several iterations of the above

There were few projects that appeared to follow a more formal requirements management process. In these cases, the requirements process was similar to the software development process and was handled in the same manner. - *Is this how it should be?* For those projects that included verification, the actual activities were dependent on the type of system being developed. Some of the projects included development of concepts, procedures, databases, and performance measures. Each project had a distinct verification process that included similarities such as utilizing existing reference standards as ICAO rather than development of a unique verification process.

Additionally, the AP5 work team found that the definition/perspective for a *requirement* differed among projects (and practitioners) depending on the subject matter expert, type of project (technological versus process versus R&D) and the practitioner's level of expertise in the requirements process. There is clearly the need for harmonized agreement to describe operational concepts and technical enablers.

6 RELATING REQUIREMENTS TO VALIDATION AND VERIFICATION

The OCVSD focuses on validating operational concepts. One important principle is that the ATM System Users (stakeholders) who 'validate' a concept are not researchers. Validating a concept is generally done with reasonable certainty if the evidence presented to the stakeholders is representative of the potential end-system.

This raises two important issues:

1) How do we ensure that what is being 'validated' as a concept in an R&D environment is close enough to the eventual end-system to ensure that all the trials and evidence including safety case and business case remain relevant and may even be used by safety regulators as a way of ensuring a safe system is being built before it goes live, and
2) How to ensure that the documentation of the concept of operations being tested (validated) is accurate, taking into account the latest evolution (this will include requirements).

In order to ensure a relevant programme of validation activities, it is essential to have accurate methods for documenting the concept. The most commonly used methods for concept documentation are the description of 'operational concept' and 'concept of operation'. The operational concept description stays at a relatively high level setting out aims of the concept which should remain reasonably constant through R&D. The 'concept of operations' is a more detailed description of an instance whereby operational procedures and technical enabler performance capabilities can be identified. This description could change dramatically through R&D and it is at this level that validation and verification become particularly relevant.

Along with the 'concept of operations' (ConOps) descriptions, it is expected that 'requirements' will be documented. Similarly, the 'concept of operations' and requirements, together, will describe the eventual end-system in sufficient detail to enable system procurement and system design, which may require the support of scenarios.

The evidence from validation activities must be checked for relevance. As the 'concept of operations' and associated 'requirements' evolve during R&D the early results may lead to modification of requirements at an early stage when the costs to apply the changes have a lesser impact than they would if the changes were applied during development or following implementation. During the R&D phase, key aspects may need to be retested, and other findings might become obsolete due to shifts within the 'ConOps'. That is to say, that there needs to be a mechanism to ensure that the system being built and tested (validated) is also the system that is being described and that evolutions during R&D are clearly accounted.

7 RECOMMENDATIONS AND NEXT STEPS

As stated in the introduction, the surveys were carried out in the context of the development of a Verification Strategy in order to complement the already delivered Operational Concept Validation Strategy Document (OCVSD). It is now commonly understood, that requirements are a prerequisite for a Verification Strategy.

The survey of current terminology and applicable standards as well as of the current practices in projects to collect requirements suggests that the goals of the Verification Strategy be:

1) To agree on a common terminology and guidelines to better define the expected contents of a description of an Operational Concept / Requirements. In this context the terminology / standards used in U.S. NextGen / NAS architectures should be incorporated.
2) To build a relation of concept validation with system engineering. This requires:
   a) To understand the role and influence of Technical Enablers and Architectures in the process to develop Operational Concepts / Requirements.
   b) To better understand the development processes of technical enablers and its interrelation with concept development, identify the technical maturity.
   c) To better understand the client/supplier relationship.
3) To identify processes to develop Operational Concepts / Requirements, taking into account:
   a) The appropriate interplay of
      - generic development aiming at the validity of a concept "in principle" and
      - site specific development, building on local conditions and expertise.
   b) To embed "Reality Checks" - depending on the Concept Development lifecycle. "*Reality Check*": It must be ensured that the technical enablers perform at the desired operational level when performing Concept Development activities. This needs to be done on an "in principle" level (e.g. principle performances of a Trajectory Predictor (TP)) but also on a specific/local level, taking account the specific/local conditions (e.g. performance of a TP in the real environment).
4) To provide guidelines to select appropriate standards and to "tailor" them to the identified processes.
   "Tailor Standards": Existing standards tend to be very wide (e.g. IEEE 15288 on System Engineering). In order to be useful for specific development effort, they need to be "tailored" to the specific needs (e.g. complexity, quality requirements, safety criticality, size of the project, etc).

As stated previously, the current goal of Action Plan 5 is to develop a Verification Strategy that complements the existing Validation Strategy. To that end, the following activities are suggested as a means to developing such a strategy.

1) Finalize documentation of preliminary verification activities (i.e., requirements analysis and terminology/standard review).
2) Develop initial Verification Strategy Strawman
3) Host a Practitioners' Workshop to evaluate and refine the proposed Verification Strategy.
4) Produce a final Verification Strategy

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APPENDIX A LIST OF SURVEY RESPONDENTS

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Stephen Morten	EUROCONTROL
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APPENDIX B REQUIREMENTS QUESTIONNAIRE

The Federal Aviation Administration (FAA) and EUROCONTROL have a forum to discuss and determine common approaches to validating and verifying new operational concepts. This forum is the Action Plan 5 (AP5) working group. The common validation approaches are captured in the Operational Concept Validation Strategy (OCVSD). A derivative of the OCVSD is the European Operational Concept Validation Methodology which is a reference document for European ATM R&D and the SESAR Programme.

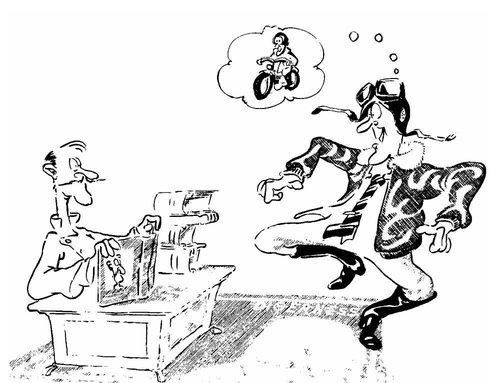
The AP5 working group is currently looking at verification issues, and recognizes that verification is closely linked to the development and management of requirements. The identification of requirements during the operational concept development process is critical to building an adequate and reliable system.

To that end, AP5 participants have developed this survey to query practitioners from both the United States and Europe regarding current R&D practices in the areas of requirements development and management including: requirements collection, requirements categorization, and requirements usage. By examining projects within both communities, the goal of this exercise is to establish consistency in terms of requirements development and management that bear a concept verification strategy that support the development of adequate and reliable systems.

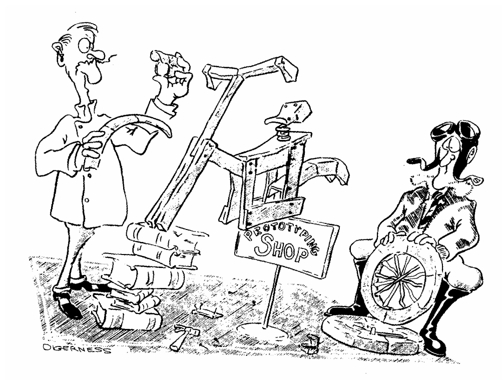
Questions for Discussion

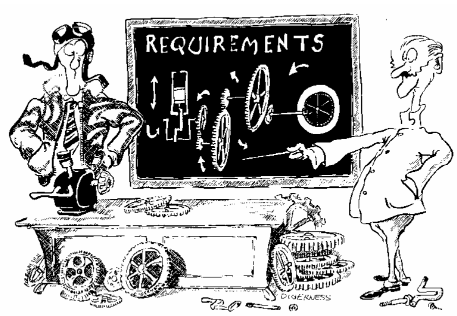
1) Synopsis of the project which is subject of this questionnaire.
   Example – concept development, implementation, technical development, were requirements important…?
2) Who was the customer - the budget holder, the end user, other (please describe their role)?
3) Below is a storyboard for film on requirements engineering.
   a) Did your project follow a similar approach to identifying requirements?
   b) From your perspective, are they in the right order? (Numbers are for identification only)

1. I need something like this.

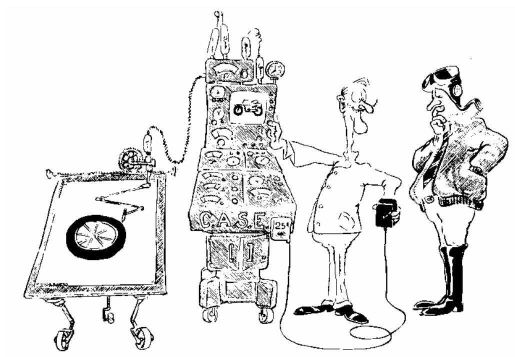


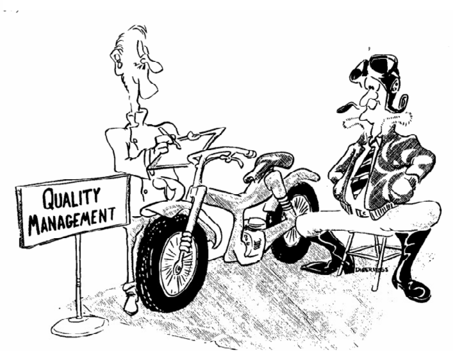
2. Additional expectations





3. A prototype 4. Capturing requirements





5. Specifications 6. Finished product

4) Briefly identify the types of requirements the project captured (operational, safety, architectural, technical, functional, system, etc.)?
5) Briefly describe each type of requirement.
6) Did the project have specific processes to develop, capture, analyze and/or manage requirements? If so, briefly describe each. Are there reference documents/processes/standards?
7) Were requirements verified and/or validated in the project? If YES, please describe how requirements were validated and/or verified.
8) Were the validate/verified requirements stable and/or adequate? Please explain your choices.

	Strongly agree	Slightly agree	No opinion	Slightly disagree	Strongly disagree
Stable (were there many versions)					

Adequate (did they need explanation)					

9) What was the impact of validation/verification activities on the value of the requirements?
10) How is acceptability of requirements checked?
11) How are problems and/or issues due to insufficient requirements or the lack of adequate documentation reported?
12) In your opinion, what are the main issues that a verification strategy should address?

APPENDIX C ANALYSIS OF REQUIREMENTS SURVEY BY PROJECT

Due to the active nature of the discussions with each project and the loose application of the questionnaire (**Error! Reference source not found.**) it was impossible to summarize the findings and map closely to the structure of the questionnaire. The analysis is therefore loosely structured into "Scope", "Development Approach" and if applicable, some additional "Observations".

C.1 AIRPORT LAYOUT PLAN (ALP) FOR THE O'HARE MODERNIZATION PROGRAMME (OMP)

Scope:

- No technology considered;
- Site specific – not generic;
- Potential impact on FAA regulations.

Development Approach:

- Highly interactive, involving end-users as well as citizens and political groups.
- Trust building through high fidelity and directly comprehensible simulations using an advanced simulator with 3D vision generation.
- Feed back from simulation was directly incorporated into the scenario for the next iteration. (Obviously there was a highly skilled and competent development team preparing and evaluating the simulations).Thus validation and requirement development was not explicit but connected to the scenario and feed back from the simulations based on that scenario.

C.2 BIG AIRSPACE

Scope:

- Required technology identified – but availability only assumed and not checked;
- Site specific – but aiming at a broader picture;
- Corresponding to V1/V2 lifecycle phase, aiming to build up knowledge and to enrich the picture.

Development Approach:

- In order to assure usefulness/relevance, a specific location was selected for experiments;
- A prototype was iteratively developed using documented requirements and a process to further develop them by the development team – trust and confidence was however achieved within the teams through the use of the prototype;
- A communication between the ANSP Operations and the manufacturing industry was established during this R&D phase.

Observations:

- In summary the progress achieved is good – however not good enough to go forward to implementation.

C.3 ITEC

Scope:

- Starting from pre-established Operational Requirements to produce System Requirement Specifications to allow the production of necessary software.
- High technical content, driven by existing system with which iTEC has to interoperate.

Development Approach:

- Traceability between the different levels including the rationales for the connections was strictly applied;
- The Requirements Management Process was formal, validation/verification achieved through formal reviews through operational and technical staff to ensure mutual understanding;
- Feed back from review process was used for 1 iteration – issue: Fixed price project: How to manage an uncertain number of iterations?
- There was no checking of initial operational requirements nor the produced specifications e.g. through prototypes.

C.4 AMAN AT MUNICH AIRPORT

Scope:

- Strictly site specific on a special location;
- Develop an "Operational Prototype", in other words the final system.

Development Approach:

- Based on limited ability of operational staff to describe requirements;
- Avoiding "ab initio" definition of requirements, concentrating on a learning by doing process;
- "Operational prototyping", meaning prototyping in the relevant operational context based on a dialogue between developers and the future users in short cycles (2 – 4 weeks per cycle over a period of about 2 years). (A similar approach is known as "Rapid Application Development" (RAD)).
- No explicit requirements identification but WYSIWYG approach – literally: Once the prototype is agreed it becomes operational.

Observations:

- Once the "prototype" is established, requirements could be "reengineered" but is not really necessary any longer;
- Architecture approach needs to be stable.

C.5 EMMA2

Scope:

- Development of an advanced concept.
- Development of generic requirements to define the concept and specific local requirement adaptations for the involved test sites (airports).

Development Approach:

- Formal process to solicit, document and review requirements.

Observations:

- How to do reality checks without having the reality due to the uncertainty of the more distant future?
- Validation of requirements discovered to be more complicated than pure verification. Positive validation results do not automatically confirm the value of a specific requirement.

C.6 SELF CHECK IN FOR AN AIRLINE (CKI)

Scope:

- Modernization of a specific application within a specific existing technical environment;
- Starting from a broad intention ("modernization") resulting in the ready for use application software.

Development Approach:

- Explorative:
  - Identification of modernization of user interface through mock up;
  - Understanding sometimes "secret" issues stemming from integration into existing environment, documentation of requirements following the facts.
  - External independent verification using automated tools.

Observations:

- Decision making monopolized by the customer project leader;

C.7 EUROPEAN AIS DATABASE (EAD)

Scope:

- Established functionality, aims at reorganization of operation. Increase of international collaboration;
- Architecture had to match organizational circumstances.

Development Approach:

- Focused on identification of "constraints" stemming from organizational issues.

- Where available, standards were used to verify e.g. safety and security.
- Introduction of EAD in incremental steps, using a formal change request procedure to adapt to the real environment.

Observations:

- To maintain adequate project management discipline in a complicated multi organization and political environment.
- To handle conflicting interests.

C.8 FIRST ATC SUPPORT TOOL IMPLEMENTATION (FASTI)

Scope:

- Develop useful controller tools: Understand the operational and technical implications of the tools: To develop a useful initial working approach;
- Progression from initial Operational Requirements to understood/validated Operational Requirements to System Requirements.
- Initial conditions were perceived as adequate by the development participants with statements such as "We have enough requirements – we need practical guidance material";

Development Approach:

- Building on experiences of pioneer users of early variants of the tools:
- Thereby building up experience and complementing it with e.g. r/t simulations.
- Not focusing on stringent requirements but more providing a framework in which the different organization can individually adapt to there local circumstances.
- Share experiences and provide guidelines for local adaptations, more informal.

Observations:

- The initial Operational Concept resulting from an expert task force was not realistic and needed substantial rework in order to become useful;
- There have been many constraints for the tools resulting from the existing infrastructure (legacy) into which the tools had to be integrated
- The performance of the different tools varies strongly. This is mainly due to the performance differences of the Trajectory Predictor which is again strongly dependant on the quality of the available data.

C.9 CONTINENTAL RVSM EUROPE

Scope:

- Established functionality, ICAO standard, already implemented in other region;
- Organizational and legal focus on safety case (separate for operations, transition between RVSM – non-RVSM airspace, change over day), transition and post implementation monitoring.
- Support to individual states, in particular for their safety cases.

Development Approach:

- Establish, maintain and track Master Plan based on existing experiences from RVSM introduction into other airspace – but
- No formal validation/verification.

Observation:

- Requirements for the post implementation Height Monitoring Units need to be established.

C.10 EUROPEAN INITIATIVE: SAFETY NET DEVELOPMENT

Scope:

- Requirements for the development, configuration and use of safety nets as part of a European safety initiative following the Überlingen accident
- High level minimum specification with guidance material on how to comply with these requirements.

Development Approach:

- The method used was to bring all the (known) best practices in Europe together. From this material, under the responsibility of a task force, specifications and guidance material was developed;
- Validation/verification mostly through operational expertise of task force members through expert judgment.
- Where applicable existing EUROCONTROL safety standards were applied.

Observations:

- "Validation" is essential. Theory is nice but requirements should be 'practical'.

- After reviews, etc. a practical case should be developed to 'test' if the requirements are appropriate.

C.11 STATISTICAL ANALYSIS SYSTEM (STANLY)

Scope:

- Development of an Operational Prototype, allowing for initial operations, as a first step to a fully operational system to be developed later.
- Site specific

Development Approach:

- Based on a German military standard, tailored to the prototyping approach.
- Initial functionality agreed by a task force, building on existing manual procedures.
- Additional focus on data acquisition from a heterogeneous legacy system environment that first had to be identified and then integrated into the new system
- Strong link to operations through collaboration with operational experts and staff representatives.

Observations:

- Initial approach for data acquisition and fusion was naïve and had to be completely reinvented.
- Following first experiences with operations of the operational prototype, the requirements had been reengineered from the prototype, which included optimizations and documentation according to the military standard. The final system was built according to that standard.

C.12 PROJECT X (PROJECT NAME NOT PROVIDED BY RESPONDENT)

Scope:

- Development of criterion measures of job performance for air traffic controllers to validate selection procedures.

Development Approach:

- Operational requirements; simulated and PC-based environments were used to criterion measures for on the job tasks
- Parts of the project occurred simultaneously with the criterion development.
- Computer based performance measures were developed according to established methodology; requirements for the simulation phase of the project were developed “on the fly”
- Several checklists were developed to measure performance and machine-based objective measures were identified. The reliability of the checklists was tested on several occasions and a standardization guide was developed to inform raters about criteria used to make ratings.

Observations:

- Challenges dealt with developing items and scenarios that reflected characteristics of the operational environments across facilities, without requiring specific knowledge of airspace or letters of agreement describing specific procedures.

C.13 PROJECT Y (PROJECT NAME NOT PROVIDED BY RESPONDENT)

Scope

- Identify necessary data for users of trajectory negotiation tool.
- Determine more useful and efficient procedures for using the tool.

Development Approach

- No specific process used to develop requirements – timing data, communication data, workload data, and operator error was captured and analyzed to develop requirements.
- Gathered through questionnaires and debriefs.
- No formal validation

Observations

- Problems/issues due to insufficient requirements not usually reported or documented except maybe in a paper or presentation.

APPENDIX D LESSONS LEARNED FROM LL'99 WORKSHOP

In discussions internal to EUROCONTROL, it was observed that many findings of the survey are similar to those identified in the workshop "Lessons Learned" from ATC Service Providers - Industry Suppliers Relations acquired through Implementation Projects workshop (LL'99), held 11-12 February 1999 at the EUROCONTROL HQ. Below is a summary.

The Chairman opened the discussion on the following issues:

- The most important issues when putting a system into operation;
- Tailor-made system versus common baseline;
- Firm fixed price contract versus time & material contract;
- Requirements.

The following issues and concerns hereunder came out of the discussion:

1. The most important issues when putting a system into operation

The most important issue is the acceptance of the system by the end-user. User acceptance is the key to success but it's difficult to get the acceptance of a large amount of users. The solution could be to identify an operational authority that represents the users.

In order to have acceptance for new functions, you need to start from a baseline system and implement the new functions in incremental steps, for a period of 3 to 4 years.

According to the Industry point of view, it is important to have realistic expectations based on clear requirements and realistic time scales. Changes are inevitable; both sides must admit the necessity for change management.

Clear programme management with appropriate authority on both sides is needed for quick decision making.

Intercultural differences are not as important as understanding the behavior of the individuals; it allows for actions to be taken to avoid conflicts. Intercultural differences are not limited to countries but also apply to enterprises or teams within enterprises.

2. Tailor-made system versus common baseline

Common requirements are not to be seen as a problem. One line of evolution for all the countries in Europe brings no alternative in the case of failure, contrary to different interoperable systems with varying configurations. Standard interfaces are available. The need for interfaces is not limited to systems but is also applicable to sub-systems and components.

We must recognize that the controllers' way of working is different in every country, even in every centre. As a consequence the systems cannot be the same everywhere. EUROCONTROL has a potential role to harmonize the concept of operations.

For Industry, the maximum reuse of system components is important; it allows them to decrease the cost and to make profit. It is difficult to start with a clean sheet of paper as customers are not ready to pay for it. The system must be built incrementally, but this can imply an increase in cost.

For longer-term solutions, there is no unanimous way of going further. Industry has to take some risk going one or the other way, either on their own initiative or following a common solution which does not initially always go as planned.

Industry does not influence the elaboration of requirements, but they can give advice to the customers, which always make the final decisions.

If standard systems could be realized, the cost of route charges would only decrease by about 5% a year. Tailor-made systems are not realistic; interoperability, interfaces between systems and sub-systems will help us to achieve our objectives.

The ATM world becomes more business/competition oriented. Management is not interested by the system itself anymore, but wants to be assured that a system is satisfying the users' needs. Competence is more and more difficult to find. There is a need to pool resources, because the ATC providers cannot afford to do it nationally anymore.

There is a need for common understanding on architecture, system design, interfaces and other system aspects.

Industry stressed the need for more involvement from other states, other than the ones usually present at international meetings.

3. Firm fixed price contract versus time & material contract

The Swiss model was considered as a good approach (it is a way to objectively vary the price in time), but ATS Providers must be careful that they respect the local contract regulations and for the European Union Member States, the European Union directives.

4. Requirements

Objectives must be very clear; you must know what you want. Currently, there are a lot of requirements; sometimes they are very detailed and it's very difficult to bring in know-how from Industry.

In Calls for Tender, there are a lot of different levels of requirements (operational requirements, engineering requirements, functional specifications, etc.).

A possible way to manage the requirements is to classify them as follows:

- ***Mandatory requirements:***
  a small number of requirements,
  as much detail as possible,
  they are very important and must be fulfilled.
- ***Non-mandatory requirements:***
  they do not need to be so detailed;
  they can be fulfilled or alternatives can be proposed.

It would be nice and easy to have the black box approach (plug-and-play systems) but ATC systems are too complicated. Co-operation between the ATS Providers and Industry is the keyword.