Improvement of E-OCVM Transition V3 → V4 Study Report

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CONTENTS

EXECUTIVE SUMMARY

The European Operational Concept Validation Methodology (E-OCVM) is established in the EC/EUROCONTROL collaboration in ATM R&D. This study analyses further what is required or considered beneficial when a concept developed by R&D is validated and ready to be converted into an operational system. It addresses technical issues and provides detailed information for the follow-on of the E-OCVM process, namely the transition to industrialisation. It shows how the transfer of the results and data of the previous phases (mainly: documentation, simulations, prototypes and "know-how" gained) contribute to industrial development and implementation, resulting in operational benefits, i.e. increasing capacity. Regulatory and administrative issues (e.g. the acquisition process) are out of the scope of the study.

The findings and recommendations can be summarized as:

- Use a guideline for concept specification/documentation,
- Take care that all necessary technical standards (ICAO) are in place,
- Use tools supporting UML-notation,
- Ensure transfer of soft skills,
- Establish configuration control and change management early,
- Ensure co-operation of all those concerned,
- Use a phased and incremental approach,
- Prepare for interoperability.

Standardisation is considered beneficial for two reasons: firstly, common engineering standards (as documentation guidelines) promote guidance to the reader and assist in having covered all relevant issues; secondly, technical standards (as ICAO SARPS) enable interoperability.

Following guidelines for concept documentation within the R&D work is considered beneficial, regardless of the guideline chosen. The study uses "Guidelines for Approval of the Provision and Use of Air Traffic Services supported by Data Communications **[ED-78A]**" as a distinctive example. With such guidelines most of the information required to continue is already available from concept validation. Some parts may have to be re-grouped however. The main purpose of the documentation is to communicate with the "successors": first with the stakeholder(s) involved in the decision to continue, thereafter with the engineers going to build the system. The validated operational concept, generated according to such guidelines and providing a picture of the envisaged services (i.e. more than just "requirements") will contain the required information.

Industrialisation shall not be started as long as the required technical standardisation (esp. from ICAO and similar bodies) is not mature.

Tools presently used for system development support UML-notation. If this notation is also used in the operational concept, it will ease including the information in the subsequent documents.

Transfer of "soft skills" (the knowledge gained during the previous phases) may essentially support the implementation process. In most cases it will be worth to keep "key personnel" engaged across the phases.

The processes (validation of the operational concept, establish technical standards (ICAO), the implementation, test, pre-operational use, certification and entering into service) take time. During this time new evolving technology may affect the concept. In order to trace these changes, configuration control and change management shall be installed as early as possible.

Capacity improvements in today's ATM-systems are mainly achieved using a co-ordinated approach, including data exchange with other ATM-systems and the on-board equipment. Data exchange with airline and airport systems may further contribute to improved use of the capacity. This increases the complexity of the systems and requires established technical standards and procedures. A phased or incremental approach may ease implementation of these complex systems.

In order to maintain competition within the industry, the requirements shall address "interoperability" between different ATM-systems, and also between ATM and airline operations as well as airport systems. Besides regulatory effort required, this will help to technically implement the "Single European Sky".

1. INTRODUCTION

1.1 Purpose

The objective of this study is to continue the generic approach as provided by E-OCVM (ref. **[E-OCVM**], it is assumed, that the reader is familiar with E-OCVM), and to add details to the transition V3 → V4 within the validation process, namely the hand-over of the R&D results to the industry to "build the product". This study aims to define which results are beneficial to ease the hand-over from R&D to industry.

The R&D results at the end of E-OCVM phase V3 comprise:

- Validated Operational Concept,
- Data used for validation, simulation results, and prototypes built,
- Cost Benefit Analysis,
- Safety Analysis.

The industry will thereafter start its own "workflow", comprising mainly [1]:

- System analysis (present status, changes requested),
- Top level design (system architecture),
- Low level design (modules, classes),
- Implementation (production, programming),
- System integration,
- Verification (testing).

The study also aims to demonstrate how R&D can pave the way for industry to deliver the desired products, and how R&D can assist the industry during the production phase. The information provided by this study is intended to generate an improved mutual understanding of the involved parties in the transition from the phase "Integration" (V3) to the phase "Pre-Operational" (V4).

1.2 Scope

Within the validation methodology outlined in E-OCVM, the transition V3 → V4 is not detailed. The main part of R&D activities is considered to end with the phase V3: the exercises are completed (simulations are run, prototypes are built), and the Operational Concept is "validated". It is assumed that all of the information required is available, however may need some additional "sorting" or "re-structuring".

It will be shown what helps industry to start their work, and how R&D may support the following phase V4 by using the specific knowledge gained during the previous phases V0 to V3, thus minimising the risk that the result of the industrialisation will not satisfy the user's needs.

[1] The phases may overlap and iterations may be included. Modern development environments provide increased flexibility, eliminating limitations of the traditional "waterfall"-model.

1.3 Limitations

There are some limitations to this study to be considered:

- The standards addressed in this study reflect the current state and may change over time, influencing even a generic approach;
- Compared to the SESAR approach [2] (ref. **[SESAR]**), this study concentrates on technical matters and does not engage in regulatory issues.

All statements reflect the personal opinions of the authors, who specified, implemented and tested many systems and components over a period of some 30 years for ATM and other applications.

1.4 Intended Audience

The intended audience of this document is mainly R&D and Industry. Besides, stakeholders are also addressed, as they are involved to inspect the R&D results (especially costs & benefits) and prepare a budgetary decision.

1.5 Structure of this Document

The "Executive Summary" may be found at the beginning of the document.

Chapter 1 provides an introduction, addressing purpose, scope, limitations and intended audience of the study.

Chapter 2 discusses the transition V3 → V4 in more detail, and provides recommendations for the conduct of the transition.

Chapter 3 covers additional issues, namely for cooperation during the subsequent phase between R&D and industry, as well as for the communication with "planning tools" informing the rest of the community about ongoing development thus helping to avoid duplicated efforts.

Chapter 4 summarizes the conclusions of the study.

In addition to the examples given inline in the text, three examples (programmes) have been selected to illustrate the findings of the study in chapter 5.

To support referencing, findings are marked shaded blue, whereas recommendations are marked shaded green in chapters 2 and 3. The references are included in the Executive Summary, the Conclusions and the Examples.

1.6 References

[CAATS-BP] CAATS Best Practices Manual Version 1.0
Date: 13.10.2005
Link: www.eurocontrol.int/valug/gallery/content/public/CAATS best practices Manual.pdf

[2] Some of the deficiencies mentioned in SESAR (insufficiently coordinated, partly duplicated R&D) are already addressed by Eurocontrol (refer to: LINK2000+, E-OCVM, ECIP).

[CARE-ASAS] CARE-ASAS Description of a first Package of GS/AS Applications Version 2.2
Date: 30.09.2002
Link: http://adsb.tc.faa.gov/RFG/care-asas-a5-02-040.pdf

[C-ATM] C-ATM Detailed Operational Concept Version 1.5
Date: 12.01.2006
Link: http://www.c-atm.com/documents/DetailedOCD.pdf
and: 5 OSEDs available in zip-format at:
http://www.c-atm.com/documents/OSED.zip

[ECIP] ECIP 2006-2010 Detailed Objective Description Version 1.0
Date: 20.07.2005
Link: http://www.eurocontrol.int/ecip/gallery/content/public/ecip DOD 20062010.pdf

[ED-78A] Guidelines for Approval of the Provision and Use of Air Traffic Services supported by Data Communications
Date: December 2000

[EMMA] EMMA OSED, ORD and TRD (as well as validation documents) are available at:
http://www.dlr.de/emma/temmaDocs/emmadocs.htm

[E-OVCM] European Operational Concept Validation Methodology
Date: 11.04.2005
Link: https://www.eurocontrol.int/eatmp/vdr/doc/E-OCVM.pdf

[FASTI] First ATC Support Tools Implementation (FASTI) Operational Concept Version 1.0
Date: 05.07.2006
Link (to all public documents of the programme):
http://www.eurocontrol.int/fasti/public/standard_page/Library.html

[ICAO9694] Doc 9694 Manual of Air Traffic Services Data Link Applications Version 1.0

[LINK2000+] LINK2000+ Baseline – Pioneer Phase Version 1.2
Date: 07.03.2006
Link:
http://www.eurocontrol.int/link2000/gallery/content/public/files/documents/Link 2000 Baseline Pioneers (1.2).pdf

[NEAN] NEAN Final Project Summary and Conclusion Report Version 1.0
Date: 27.05.1999
Link:
https://www.eurocontrol.int/eatmp/vdr/doc/vdr_references/neanfinalprojectsummary_report.pdf

[SESAR] SESAR Definition Phase Deliverable 1 Version 3.0
Date: 31.07.2006
Link:
http://www.eurocontrol.int/sesar/gallery/content/public/docs/DLM-0602-001-03-00.pdf

1.7 Acronyms

ACARS	Aircraft Communications Addressing and Reporting System
ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependant Surveillance – Broadcast
AFTN	Aeronautical Fixed Telecommunications Network
AGDL	Air Ground Data Link
ANSP	Air Navigation Service Provider
ARDEP	Analysis of R&D in European ATM
ARINC	Aeronautical Radio Incorporated
ASAS	Airborne Separation Assistance System
A-SMGCS	Advanced Surface Movement Guidance and Control System
ATCO	Air Traffic Control Officer
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
CAATS	Cooperative Approach to Air Traffic Services
CARE	Co-operative Actions for R&D in Eurocontrol
C-ATM	Co-operative ATM beyond 2012
CDM	Collaborative Decision Making
CPDLC	Controller-Pilot Data Link Communications
CIDIN	Common ICAO Data Interchange Network
DAP	Downlink of Aircraft Parameters
DFS	Deutsche Flugsicherung
DGAC	Direction Générale de l’Aviation Civile (France)
DSNA	Air Navigation Services Department (DGAC France)
ECIP	European Convergence & Implementation Plan
EMMA	European Airport Movement Management by A-SMGCS
E-OCVM	European Operational Concept Validation Methodology
ERATO	En-Route Air Traffic Organizer
ESSAR	Eurocontrol Safety Regulatory Requirement
EUROCAE	European Organisation for Civil Aviation Equipment
FANS	Future Air Navigation Systems
FASTI	First ATC Support Tools Implementation
FHA	Functional Hazard Assessment
Gatelink	W-LAN at the gates (airports)
GPS	Global Positioning System
ICAO	International Civil Aviation Organisation
IEEE	Institute of Electrical and Electronics Engineers
IFACTS	Interim Future Area Control Tools Support
INTEROP	Interoperability Requirements
iTEC	interoperability Through European Collaboration
LCIP	Local Convergence & Implementation Plan
MONA	Monitoring Aids
MTCD	Medium Term Conflict Detection
MUAC	Maastricht Upper Area Control Centre
NATS	National Air Traffic Services (UK)
NEAN	North European ADS-B Network
OHA	Operational Hazard Analysis
OLDI	On-Line Data Interchange

OPA	Operational Performance Assessment
OSA	Operational Safety Assessment
OSED	Operational Services and Environment Document
OSEIC	Operational Services and Environment Information Capture
RTCA	Radio Technical Commission for Aeronautics
R&D	Research & Development
SARPS	Standards And Recommended Practices
SESAR	Single European Sky ATM Research
SPR	Operational Safety and Performance Requirements
SSR	Secondary Surveillance Radar
SYSCO	System Supported Coordination
TCAS	Traffic Alert and Collision Avoidance System
TCP / IP	Transmission Control Protocol / Internet Protocol
TIS-B	Traffic Information Service - Broadcast
VAFORIT	Very Advanced data processing Operational Requirements Implementation
VDL	VHF Data Link
VHF	Very High Frequency
Vx	Phases of the E-OCVM process, namely: V0 ATM needs V1 Scope V2 Feasibility V3 Integration V4 Pre-operational V5 Operational
W-LAN	Wireless Local Area Network
XML	eXtended Mark-up Language

2. THE TRANSITION V3 → V4

In order to achieve a successful transition V3 → V4, four issues are considered essential:

1) Guidelines and standards,
2) Documentation,
3) Transfer of "soft skills",
4) Establishment of a focal point.

2.1 Guidelines and Standards

The term "guideline" in this study covers rules for the formal structure of documentation and the conduct of development projects.

With the term "standard", the technical standards as provided by ICAO (SARPS), IEEE, RTCA and similar bodies are addressed.

2.1.1 Documentation Guidelines

Industrialisation normally involves the concerted collaboration of many persons, up to several hundreds, working for different companies. Therefore all documents of a project must be produced according to a common guideline (i.e. guidelines like ED-78A, DoD-STD-2167A [replaced by MIL-498]), to make sure the reader of the documents maintains orientation where to find what. Nearly any common documentation standard may be applied; generally one standard should be sufficient. Especially for a concept developed by several teams, it is considered beneficial when all participating bodies use the same documentation standard. The standard(s) used depend on the topic (e.g. there are specific ATM and military standards existing).

F 1: Documentation Guidelines ease Orientation

All parties involved should have a common understanding how to use the guideline (and where to expect different issues). The guideline itself appears to be less important (and may change over time).

Guidelines should be applied to the form of the specifications. At present, a clear description of requirements can be achieved by the traditional "shall"-notation, or by using UML "use cases" notation [3]. The advantage of the "use cases" is that they allow a presentation of the envisaged "working models", showing actors, functions and information exchanged, including descriptions of situations which require an actor to act / react and the expected results. Both methods do NOT automatically assure that the description is complete, consistent and verifiable. Looking at an example (see ref. **[C-ATM]** [4]), the

[3] ED-78A provides detailed templates for the description of communication flows. These templates shall not be "re-placed" by "use cases", but may be augmented by "use case" descriptions. "Use cases" shall be used, if no specific detailed guideline is provided (e.g. non-data-link applications).

[4] C-ATM calls the documents "OSED". It has to be mentioned that the standard ED-78A does not require the "operational requirements" to be expressed in the form of "use cases", as its use has been intended only for "data link applications". C-ATM provides OSEDs also for non-data-link applications. ED-78A states under 1.3.2.1: "The OSED facilitates the formulation of technical and procedural requirements based on operational expectations and needs and is updated as necessary throughout

graphical presentation of the use cases is "enhanced" by addition of SADT-diagrams, showing "Input, Processing and Output" in a graphical presentation. Having in mind that the documents are mainly used for communication between operational personnel, R&D and industry, any method leading to increased understanding of the problem and its proposed solution (from an operational viewpoint) is helpful.

However, if methods are mixed (e.g. inclusion of SADT-diagrams while using UML-notation), it will not be possible to continue the design phase with the same tools used in the requirements phase. Modern development environments can easily handle UML-notations covering different phases (requirements, architectural design, low level design and finally preparing the information for implementation and testing [with another development environment, which continues seamlessly with the information provided by the first tool]). Normally the development of software is required. These tools additionally allow for updating the design documentation by inspecting the software, thus keeping the design documents aligned with the final solution.

R 1: Use UML Notation, prepare "Use Cases"

During programming, the second (implementation oriented) development environment allows for "re-factoring" (changing names of modules and variables in a consistent way within a project, allowing re-placing parts). This provides reasonable flexibility for "late changes".

R 2: Use compatible Development Tools

The promises of the tool supplier shall not be over-estimated: There is no automatism guarantying consistency throughout the documentation, but modern tools provide at least a considerable amount of "assistance", thus increasing productivity, which tends to make the development more flexible and less expensive.

2.1.2 ATM related Procedural and Technical Standards

As ATM requires international standardisation these standards have to be established before starting industrialisation [5]. Relevant standards are mainly provided by ICAO (SARPS), EUROCAE, RTCA, IEEE, and ARINC. They are required for interoperability.

F 2: Technical Standards (ICAO) required for Interoperability

With respect to communication, ATM is shifting from proprietary standards (AFTN, CIDIN) [6] to more general ones (e.g. TCP/IP), which eases implementation (and saves costs).

Concerning data link applications, it is required that the standards and procedures are established before both the ground as well as the on-board systems can be produced for operational use [7].

the coordinated requirements determination process. The OSED captures requirements that have been derived and/or validated as being necessary for a particular operational service." Utilising "Use Case" Notation may even replace the need for additional "technical requirements".

[5] A negative example to underline this is the co-existence of two data links (FANS1/A and ATN) for the same purpose, causing ground systems to be able to "talk to both airborne systems".

[6] These standards were required and beneficial at the time they had been established.

When discussing CDM, this also applies to aircraft operators and airports. Although each airport will be connected to a specific ATM system, it appears beneficial to be prepared for interoperability in this area.

2.2 Documentation

The main reason for documentation [8] is to transfer knowledge to those who follow in the project: the concept is a collection of ideas from the operationally engaged personnel first to R&D, later handed over together with the requirements to System Engineering. On the side of the industry, the system architects will prepare information for the system designers and the developers (with respect to software: the programmers). Both R&D and the system designers will create documents describing the verification process (testing). It is considered a task of the responsible manager to select the documentation. It might be necessary to adjust parts supporting a specific solution to a more generic description, thus preparing for interoperability instead of promoting proprietary solutions.

F 3: Documentation to be used for Transfer of Know-how

By all means, preparing documentation must follow two general rules:

1. Do not prepare any document which nobody is supposed to read.
2. Write the document with respect to the intended audience (make it understandable to the expected readers).

Needed are:

- The validated Operational Concept and
- Supporting Documentation.

Parts of the documentation will require a "re-arrangement" to meet the needs of the intended audience. Especially the managers concerned with budgetary decisions require "condensed" information. The summaries contained in the documents (if prepared appropriately) may serve as an easy adaptable basis.

2.2.1 The validated Operational Concept

Irrespective of the tools and standards used for the production of the validated Operational Concept, at the end of phase V3 a document should exist containing the complete and consistent specifications for the requested system development or change (covering also all "special cases", exceptions and constraints).

An example shall explain this in more detail.

All European projects of the domain "ATS supported by data link applications" are required to use the standard "Guidelines for Approval of the Provision and Use of Air Traffic Services supported by Data Communications" (ref. **[ED-78A]**), being derived from ICAO Doc 9694 (ref. **[ICAO_9694]**). The standard ED-78A describes a set of documents to be prepared for any data link application, and provides guidance how these documents should be structured. The main documents are:

[7] Please refer to the ADS-B example at the end of this document and to **[NEAN]**.
[8] Besides elaboration of ideas.

- Operational Services and Environment Document (OSED),
- Operational Safety and Performance Requirements (SPR), incorporating the results of Operational Safety Assessment (OSA) and Operational Performance Assessment (OPA),
- Interoperability requirements (INTEROP).

This standard is (besides the specialities dealing with data link addressed in the templates) considered to be applicable also to non-data-link applications. The C-ATM project (ref. **[C-ATM]**), looking at ATM in general, Flow Management, En-Route and Terminal Operations, constructed its documents very close to the standard.

R 3: Prepare the Concept according to a Standard like ED-78A

R 4: Requirements expressed in UML "Use Case" Notation

2.2.1.1 Operational Services and Environment Description (OSED)

A description what is expected to be contained in an OSED is given in ED-78A (chapter 2.2.1):

> The OSEIC captures, in a systematic and formal way, the operational objectives of the operators and the ATS providers, in terms of the implementation of ATS supported by data communications. All potential applicants including the operators, aircraft modifiers, system integrators, equipment designers, ATS providers, communication service providers and approval authorities are involved in the OSEIC process. Cost benefit analyses may influence the coordination process to decide what will be included in the OSED. The information captured during the OSEIC process is assessed and validated by the OSA, OPA and IA and may have to be modified as a result of those assessments to produce an updated OSED.

Note: Both the E-OCVM and the ED-78A consider the process to achieve a "validated Operational Concept" resp. an "updated OSED" as iterative. The iterations assure that all documents are consistent and the concept can be called "validated".

The level of detail to be achieved in the Operational Concept does not depend on whether the concept is at programme level or at project level [9]. In both cases, the specifications have to be consistent and verifiable [10]. Despite using modern development environments, "flexibility" of the industry to include additional topics addressed late in the development process will be limited and may effect time and money. However, the specifications should be generic enough not to promote any specific solution of one specific system provider.

Competition in industry shall be sustained and continued, but interoperability among all products will contribute to improved usage of the available capacity. In order to maintain competition within the industry, the specifications shall address "interoperability" between different ATM-systems, and (concerning collaborative decision making) also between ATM and airline operations as well as airport systems. This will help to technically implement a "Single European Sky" (besides regulatory effort required).

[9] In case a programme is split into different projects, the detailed specifications should only be formulated at project level to avoid different statements at different levels.
[10] The specifications shall allow for verification whether they have been correctly implemented.

R 5: Prepare for Interoperability

At the end of the description of each detailed ATS-function supported by data communication (after scope, expected benefits, anticipated constraints and human factors), there should be a description of the "coordinated requirements". In ED-78A the term "coordinated requirements" means much more than just "requirements" [11]. It addresses the operational service envisaged and the working environment, thus providing enriched specifications based around models of the future system.

Validation "ensures that requirements are necessary and sufficient for operational implementation. It may include analysis, simulation evaluations, prototype testing, and operational trials"(refer to **[ED-78A]**, chapter 2.2).

This information will be used by the industry to prepare (generally) a "fixed price", "fixed date" offer. The contract shall prepare for negotiations required to fix problems detected late. The contract may also include parts to be mutually agreed upon during the first phase of the development (e.g. discussion of the HMI) or even be postponed to late phases of the development (e.g. final decision on hardware to be installed).

It is well understood that during the implementation process both parties (the customer as well as industry itself) will "learn" when working on the details of the requested product. Modern development environments assist this learning process by re-factoring or re-engineering [12]. The required negotiations shall be anticipated in the contract.

R 6: Prepare for Negotiations (of late changes) in the Contract

2.2.1.2 SPR and INTEROP

Besides working on the Operational Concept (laid down in an OSED), the documentation produced until the end of phase V3 should cover Operational Safety Requirements, Operational Performance Requirements (if ED-78A is applied, results to be found in the SPR document) and an Interoperability Analysis. According to E-OCVM, costs and benefits have to be analysed as well (partly contained in an OSED).

The Safety Requirements shall comprise the Functional Hazard Assessment (FHA) [13].

Performance requirements include assumptions on the capacity to be handled, and response times tolerated.

[11] For detailed information, please refer to Chapter 4 of **[ED-78A]**. The document shall also describe key performance and behavioural capabilities.

[12] The flexibility gained with these development environments is considered to be limited, compared to the promises of the producer of these tools.

[13] If architectural decisions have been made (for prototypes/simulations), the basis for a PSSA is provided and it is worth to transfer the results (planned features to meet the requirements of the FHA) to the subsequent phase. It is assumed that in many cases the prototypes will not address safety issues, thus the information will not be available and may be omitted.

The benefits of interoperability with respect to both increased capacity (improved coordination between the systems) and moving towards the "Single European Sky" have already been addressed above [2.2.1.1].

2.2.2 Supporting Documentation

2.2.2.1 Scenarios and Validation Results

Data used for validation is considered beneficial firstly to the understanding of the problem to be solved, secondly for the conduct of industrial tests and last not least for acceptance testing. The same applies to simulation results.

The validated Operational Concept shall be augmented by all data used within the validation process so far. This includes (but is not limited to):

- Models of key aspects of the future system,
- Assumed traffic load,
- Airspace structure,
- Tools and simulators used during the R&D development process,
- Simulations performed with all data used, in particular the scenarios,
- All assumptions / prerequisites / limitations ,
- All validation results (including the "failed" ones).

The models of key aspects of the future system provide a quick reference to the intended changes.

The load figures may be used for verification (performance testing).

The airspace structure may influence the proposed solution.

Tools and Scenarios used may assist in the verification process (testing).

Simulations performed may also be repeated for testing the final product.

Assumptions made / prerequisites assumed / limitations anticipated also help to get a better understanding of the benefits of the ordered system.

This is especially true for the validation results (namely those, who "failed"), to provide hints to the industry, what is already shown not to work as one might expect.

2.2.2.2 Simulations performed and Prototypes built

Knowledge of the simulations performed and prototypes built will enhance understanding of the problem and the complexity to be addressed. In many cases these activities concentrate on specific issues of the proposed solution and ignore other aspects (e.g. continuity of service, robustness [tolerance to erroneous data, illegal input]).

It shall be clearly stated what the simulation / prototype contains and what has been omitted.

If an architectural description of prototypes is available (i.e. it should be in UML-notation), it can be used as "additional information" (not as a strict requirement). The results of analysis and design performed upon creation of the prototype ease understanding of the problem, which has to be analysed and designed by industry.

2.2.2.3 *Data used and Assumptions made*

All data used for validation shall be available in an easy convertible format (e.g. plain text files, XML).

The data used in validation scenarios, simulation and prototype exercises might include valuable information on both the desired functionality as well as performance.

Additionally these data might be re-used for testing (verification).

All assumptions (e.g. estimates on load figures, prerequisites, constraints [14]) shall explicitly be stated, mainly in order to enable adequate testing (verification).

2.2.2.4 *E-OCVM Case Based Views*

The Cases are considered to contain merely a "re-grouping" of already existing results. Their main objective is to assure that all special issues have been properly addressed. Input for all Cases should be the same: a clear and complete description of the ATM System / Operational Concept [15].

F 4: "Case Based Approach" to check that all Items are covered

It is assumed that most of the information is available, but may need to be re-structured/sorted. It may also be that the summaries available have to be "tailored" to the managers' and stakeholders' needs (short, strong, economic figures).

The Cases identified include:

- Business Case,
- Safety Case,
- Human Factors Case,
- Environmental Case,
- Technology Case.

The Business Case holds information about performed cost benefit analysis; it may also list the Key Performance Areas and Indicators.

A Safety Case is presenting the entirety of arguments and evidence needed to satisfy the project team, the stakeholders and the regulator with respect to Safety. In the transition phase from V3 to V4, the Safety Case merely holds the Functional Hazard Assessment FHA (or equivalent documentation) [16].

[14] When using OSED format, there will be a "constraints" section included in the document.

[15] A good description on how to create cases can be found in CAATS "Best Practices Manual" (ref. **[CAATS-BP]**). The manual addresses "ATM Validation, Human Factors and Safety"*.* CAATS „recommends the E-OCVM as the central best practice framework for validation in ATM", due to „the clear and direct possibility to make Safety and Human Factors (and other Key Performance Areas) an integral part of validation".

[16] If architectural decisions have been made (for prototypes/simulations), the basis for a PSSA is provided and it is worth to transfer the results (planned features to meet the requirements of the FHA) to the subsequent phase. It is assumed that in many cases the prototypes will not address safety issues, thus the information will not be available and may be omitted.

The Human Factors Case collects all information on intended changes in workload, operational roles, acceptability and additional education / training required. It will also address HMI.

The Environmental Case covers, besides the mainly airport related issues of noise abatement and local air quality, a requirement for ATM to keep fuel burn, delays (human time) and greenhouse gas emissions low [17].

The Technology Case will address technology and standards to be used (both documentation guidelines as well as ATM related technical standards), thus demonstrating feasibility. It is important to remember that the requested solution is supposed to be operational for quite some years. Environment, technology and concept (requirements) may change during this period. Therefore there should be some - the amount will be discussed below - “build-in” flexibility.

R 7: Prepare for Flexibility

Besides “adaptable system parameters”, flexibility may be achieved by “architectural means” i.e. by using (requiring) an “n-tier architecture”, where the presentation logic is separated from the business logic, and the business logic is again separated from the data access (DB-access layer), the devices (mediators and drivers) and the communication (protocols). The advantage of the “tiered” (or “layered”) approach is that the different parts can easily be changed or even exchanged, (mainly) without affecting the other layers, thus providing some kind of “build-in” flexibility.

What is said above is assumed to be the generally lowest detail of a requirement concerning a product’s architectural design. All other details should rest with the industry, if not special circumstances (e.g. product has to be fitted into another product, which requires using a dedicated “middleware” or comprises a “distributed application” [18]) require more precise regulation.

The warning provided in **[OCVSD]** not to jump into every modern “technology”, should be taken seriously. However, the changes in technology shall closely be traced and evaluated for usage in the area concerned.

2.2.2.5 Prepare Stakeholders Decision

With all collected results from phase V3, the material to convince the stakeholders to make a “Go”-Decision for the concept needs to be prepared; as a document and as a presentation. For this, a summary of the information available, containing objectives, cost and benefits, safety and performance will be required. This summary has to present the concept in a convincing wording, understandable to non R&D experts.

[17] The requirement to keep the greenhouse gas emissions low can be met by the creation of Functional Airspace Blocks, which are tailored to optimise traffic, despite national borders being used to determine the sectorisation of airspace.

[18] E.g. check-in kiosk, with the requirement that the software components have to be exchanged without visiting every installed kiosk and keeping track on the versions installed, causing a “Rich Client” solution and “bundles” to be named in the requirements as actually the best known (and wanted) approach.

NOTE: The remaining tasks to obtain stakeholders' decision is considered to be out of the scope of this study (part of the acquisition process).

2.2.2.6 Prepare the Acquisition Process

The availability of the documentation listed in this section [2.2] (its contents, the structure may vary according to the selected documentation standard and the establishment of a "focal point" [responsible manager]) shall be sufficient for the aim of this study.

NOTE: The further processing (ending in the evaluation of proposals) is considered to be part of the acquisition process itself, which is out of the scope of this study.

2.3 Transfer of "Soft Skills"

Besides the role of modern development tools (e.g. tools for documentation, rapid prototyping, simulators), it has to be considered that the intellect and the creativity of the personnel engaged in the process can (up to now) not be replaced by all tools available.

It is important to remember the importance of "soft skills":

- Operational experience,
- Knowledge of future demand (capacity requirements),
- Knowledge of "enabling technologies" (which evolve upon time),
- "Visionary" view of how these technologies can be used in ATM.

Operational experience is considered a key factor and should be available at ALL sides (especially R&D and industry).

Knowledge of future demand will assist in "right-sizing" the requirements.

Knowledge of the enabling technologies and their anticipated evolvement supports the preparation of realistic requirements.

It requires additional skills to produce a "vision" how these evolving technologies may be beneficial when used in the systems concerned. When using evolving technologies, it has to be assured that the respective standards are already established (or at least initiated) [19].

All these skills should be available on all sides of the project. The documentation shall be used to transfer the ideas of individuals, and to discuss it in order to improve the understanding of the problem by the "technicians" (mainly R&D and industry). Keeping key personnel engaged across the phases will additionally contribute to ease the transfer of "soft skills".

R 8: Keep Key Personnel engaged across the Phases

[19] E.g. the NEAN-trials partly didn't receive acceptance as some kind of VDL-4 was used, which at that time was not standardised in the area of ATM ("similar" technique used with JTIDS and Link 16 within military communication). The standardisation process requires time, which has to be considered in order to produce realistic planning.

2.4 Establishment of a Focal Point

To ensure an effective and successful transition, a responsible manager has to be installed as "focal point" for the coordination of the activities and measures described above. This focal point should preferably have already been engaged in the creation of the Operational Concept. It is also beneficial that this person keeps "hands-on the project" during the following phase. This enables the specific knowledge gained in the early phases to be available in subsequent actions.

R 9: Install a "Focal Point"

The focal point has several important tasks to fulfil. One of the first tasks will be to check whether the documentation produced so far is complete and may be used for the transition to the next step [20]. Another important task is to check for similar / colliding activities. Checking the ECIP (and preparation of information about the own project to be included) is probably not sufficient. All means of informal information [21] shall be used to collect information about projects in the same or similar area and to disseminate information concerning the own planning.

The focal point has also to prepare a list of applicable guidelines and standards. The technical standards addressed by the concept shall at least be available in draft version. Additionally this manager should check whether the concept touches any regulative (legal) aspects or Intellectual Property Rights.

If a "Configuration Control & Change Management" has already been installed, it shall be continued [22]. If it does not exist, the focal point has to install it in this phase. The phase may take some time [23]. Changes to the concept or in the enabling technology shall be included and traced carefully. Even if the transition requires relatively short time (compared to the time already spent by R&D, time spent for the establishment of the required technical standards, the time needed by industry for construction and certification of the product, the time required to install the new product either in the on-board or the ground systems), technology will continue to change and these changes may influence the validation results.

R 10: Install Change Management as early as possible

Finally, the focal point has to assure that the following checks are performed:

- Lack of requirement specification, be it in coverage or level of detail,
- Over-specification, resulting in unnecessary constraints,
- Gold plating resulting in extreme cost versus little benefit or white elephants,
- Quality of V3 results, e.g. ambiguous or badly scoped requirements (e.g. "shall ensure the highest system integrity"),
- Unrealistic planning, be it in schedule or development costs,

[20] This includes also checking whether the actual status is available in the VDR.
[21] E.g. consultation of colleagues at workshops, in the hallways or the cafeteria, or at the annual fair in Maastricht.
[22] Please refer also to 3.4 Configuration Control and Change Management
[23] Especially if technical standards have to be established, it takes years more than months.

- Potential instability in requirements.

It is assumed that all these topics have already been addressed in the past phases [24], but have to be rechecked before start of industrialisation.

[24] It is considered to be part of the validation activities to carefully look at the requirements.

3. ADDITIONAL ASPECTS

3.1 Co-ordination and Collaboration

Capacity improvements in today's ATM-systems are mainly achieved using a co-ordinated approach, including data exchange with other ATM-systems and the on-board equipment [25]. Data exchange with airline and airport systems (CDM) may further contribute to improved use of the capacity. This increases the complexity of the systems and requires established standards and procedures [26].

F 5: Increased Complexity

Another kind of co-ordination is required for the transfer of information collected in early phases (V0 to V3) to the subsequent "users" of this information (system engineering teams). This study already addressed the benefits of following a "standardised" or "structured" approach, especially concerning the documentation (see section 2.2).

3.2 Benefits of an "Incremental Implementation"

One method to reduce the risk of the implementation not to perform as intended is to plan an "incremental implementation", implementing first the basic features and plan the more sophisticated ones to be implemented in a later phase. This allows including "lessons learned" during the early increments in the following ones. This will not be achievable every time, but in many cases it is a well established procedure for risk reduction and opens the possibility to "tailor" the later increments, utilizing experience gained within the early ones. The CARE-ASAS programme [27], defining at present the "ADS-B Package 1", forms a good example for this approach.

R 11: Incremental Implementation

3.3 Anticipate "Learning"

Even with very precisely described, complete and consistent specifications "learning" will not stop as soon as the Operational Concept has been validated. The phases V4 and V5 may take several years. All parties, users together with R&D as well as developers, will increase their knowledge on the problem and the possible solutions. An amount of about 10 % per year of the total development cost is typically necessary to adapt the concept to the developing operational needs. An adequate amount of the budget has to be planned to keep the concept on the current during the V4 – V5 phase before set into operations.

Modern development tools will assist the developer by including late changes and controlling the impact on the other parts of the system. Additionally the

[25] It is worth to mention that with AGDL the investment in the ground structure only pays back if the aircraft also change their equipment. This normally takes some time. Procedures become even more complicated, as the ATCO has to treat those equipped aircraft different to those not yet equipped.
[26] Refer to ED-78A chapter 1:" The use of data communications between ATS providers and aircraft increases system complexity."
[27] Now integrated in LINK2000+

outputs of the development tools – especially the graphical ones – may be used to assist communication between designers (architects) and developers (programmers) as well as providing feedback to the users (assisted by R&D) that their requirements are properly understood and correctly converted into a system. These tools continue to be beneficial for maintenance and further development of the system once it is operational.

Despite the increase in productivity gained by the use of standards and development tools, the main contribution to a "good solution" requires the skills and creativity of the system engineers and their sound knowledge on the problem to be solved.

3.4 Configuration Control and Change Management

If not already established, configuration control and change management shall be installed at the beginning of the transition (otherwise continued). As the transition (and the associated processes) will take some time, the validated Operational Concept may be subject to change requests. Both technology as well as operational developments will most likely continue to evolve after the end of phase V3. A formal mechanism to collect and evaluate additional ideas will help to maintain consistency and include evolving technology wherever considered beneficial. It also allows tracing under what circumstances a specific feature has been agreed on and incorporated in the project.

3.5 Recommendations for the Transfer of Knowledge

Besides the already mentioned value of documentation and benefits of keeping key personal engaged across different phases, the following should be considered:

In order to track the "industrialisation" phase by more than just looking at the Management Plan, it should be investigated whether R&D can continue to work by:

- Participation in the checkpoints (Critical Design Review(s), Factory Acceptance Test, Site Acceptance Test),
- Adaptation of test data generators and simulators to be used together with the development system,
- Preparation of the final tests (e.g. test description, data and simulators to be used, conduct of test(s)).

Participation in the checkpoints covers a topic which is often (also within the industry) handed to "external staff" supporting the managers.

R 12: R&D participation in Checkpoints and Tests

Adaptation of test data generators and simulators to fit to the development system can best be performed by those already familiar with the data and the simulations.

Testing (verification) has (in the past) very often been an area of conflict where the producer wants to demonstrate "what is working" instead of looking for "special cases". External staff may follow a more "investigative" approach.

It may also be considered beneficial to build a reference system around the simulators and make it available to industry to support integration/system testing, and to have a tool for the further development (incremental improvement).

As already stated within the section on the “focal point” (2.4), it is considered beneficial to keep (some) key personnel [28] engaged in the subsequent phase. If many different bodies contributed to the validated Operational Concept, it will be the task of the responsible manager to suggest a selection to the stakeholders, as the decision to split the tasks also implies budgetary consequences. Generally it will be less expensive to maintain know-how in the project.

3.6 Recommendations for the Transfer of Data to other Planning (ECIP)

The presentation material created for the stakeholders’ decision is considered suitable to be entered directly into planning tools like ECIP / LCIP and the VDR. Another way to inform the others may be to make it available in the public, and establish a link from ECIP to this documentation.

R 13: Check for colliding Activities, avoid duplicated Effort

The documentation should be updated after project milestones to show the correct status of the project to the interested public.

Additionally the ARDEP “green book” shall be checked for update, at least with the start of the industrialisation.

[28] Not necessarily “Key Account Manager”

4. CONCLUSIONS

Although the phase V3 ends with a “validated Operational Concept”, there are some tasks - including an additional recheck of the results - which should be performed by a “focal point”.

Applying a documentation guideline to R&D work which already addresses besides the complete, consistent and verifiable system description also safety, performance and interoperability issues is considered beneficial for the transfer of results (use of the provided documents as specifications). Using the standard ED-78A is recommended. [R 1:] [R 2:] [R 3:] [R 4:].

International technical standards (ICAO etc.) are required to avoid duplicated on-board equipment [F 2:]. It is also required to ease coordination between different ANSPs. The standards have to be established (at least in a draft version) before start of industrialisation.

If the system description utilizes “Use Case” notation, the distinction between operational and technical requirements becomes obsolete [R 4:]. The specifications shall address interoperability [R 5:].

Besides the transfer of documentation, transfer of know-how by keeping key personal in the project across the different phases is considered crucial for the success [R 8:]. Furthermore, R&D may support verification, reusing data and simulations [R 12:].

Time needed for development of the Operational Concept and establishment of standards, as well as for implementation and certification (approval) of the results together with rapidly evolving technologies and changing operational needs, requires to prepare for negotiations (of late changes) in the contract [R 6:] [R 7:] and an early implementation of Configuration Control and Change Management [R 10:].

The project documentation (validated Operational Concept, Simulation and prototype information, Cases, supporting documents for stakeholder decision and Call for Tender) is needed for the transfer of knowledge between the project phases [F 3:].

The tools available increase productivity and allow more flexibility [R 7:]. There are now efficient, flexible and compatible tools commercially available, however no such tool replaces the intellect and the enthusiasm of man, thinking on how to use evolving technology to assist in solving operational needs.

Capacity gains in air traffic require improved coordination and collaboration among the concerned systems. This leads to increased complexity [F 5:]. In order to cope with the complexity, a phased approach to incrementally implement the changes may be beneficial. For short term developments, it may also be helpful to concentrate on only one segment (e.g. the ground segment).

To avoid double work and colliding activities, effective means shall be used to collect information about projects in the same or similar area, and to disseminate information concerning the own planning [R 13:], especially ECIP and the ARDEP “green book” should be checked and updated.

5. EXAMPLES

The following examples were selected to illustrate the findings of the study. They comprise a short description of the programme(s) and an assessment how they can demonstrate the generic items discussed within the study.

Reference to additional examples was made within the body of the study wherever it was considered helpful to illustrate the statements provided.

5.1 FASTI

5.1.1 Short description of FASTI

FASTI concentrates on short term improvements of mainly the ground system(s). It uses existing systems (or systems just under development, expected to become launched soon) for beneficial use of MTCD, MONA and SYSCO (extension of OLDI-messages). Systems analysed comprise:

- NATS (iFACTS, iTEC),
- DSNA (ERATO),
- MUAC,
- DFS (VAFORIT).

This means, FASTI looks at those systems which cover the “core area” with the maximum capacity requirements (Brussels, London and Paris [in alphabetical order]).

FASTI analyses different (implemented) approaches for their benefits and drawbacks with intensive investigation of operational (procedural) effects, focusing on “human factors” as well as addressing safety very detailed. FASTI is not supposed to prepare documents for “industrialisation”, but tries to harmonize the incremental improvement of existing systems, as well as to give advice to ANSPs on topics to be addressed when they start implementing the new functions (i.e. preparation of guidelines, recommendations with emphasis on human factors and safety). Thus FASTI is looking more for “interoperability”, assuring that a functionality considered useful does not stop at the boundary of the AoR of a dedicated ANSP. After the interfaces have been lifted to a common level, the implementation in the individual system is left to the industry (and to the specific ANSP who might intend to use the functionality offered by increased interoperability a little bit different than his neighbour).

5.1.2 Assessment

FASTI illustrates the following findings of the study

- Keeping complexity moderate (by looking only at one segment, the ground systems, F 5: Increased Complexity),
- R 11: Incremental Implementation,
- Necessary level of detail to be reached in the Operational Concept, R 3: Prepare the Concept according to a Standard like ED-78A,
- R 5: Prepare for Interoperability.

The limitation to the ground systems is considered beneficial for short term results. In the long run, the increasing capability of the on-board systems will become more and more important for improvements on the ground (AGDL).

The approach chosen by FASTI is considered to be a good example for "validation work continued in the phase of implementation", by looking at the benefits and drawbacks of systems already build, and thus helping the successors to use experience gained in projects. The "incremental approach" (to stress on harmonisation, which can be achieved within the next few years) also tends to contribute to positive results.

Though FASTI is positioned at "programme level", it provides very detailed information concerning requirements, human factors and safety by looking at different products used to increase capacity by reduction of workload (filter with MTCD, SYSCO), whilst maintaining (or even increasing) the level of safety by selectively displaying the most relevant information to assist the controller in maintaining a precise "mental picture" of the air-traffic situation.

It is expected that the goal of "seamless operation" can be achieved using this approach, and still different systems will be produced tailored to individual preferences.

In this case, data exchanged is driven from the "receiving partner" (kind of data, format and frequency) and may not – or not in this form – be required by the delivering partner, which leads to a co-operative approach.

As long as the result comprises "seamless operation", the details of different systems shall be less important. Providing the information (results of the FASTI discussions and solutions) to other ANSPs, so that they can do their own selection when deciding about changes to be incorporated in near future, seems to offer additional advantages and cost-savings (NOTE: do not re-invent the wheel).

5.2 CPDLC

5.2.1 Short description of CPDLC in Europe

Initially the aircraft operators defined their own data link, mainly handling information from the aircraft to the "operations section" (dispatcher):

- When did the flight start (off-block),
- When will the flight arrive (on-ground),

- What assistance does the flight require at one of the next destinations (maintenance).

This service (named ACARS or Aircom) was implemented by ARINC in the US and Canada, and by SITA mainly in the rest of the world in the 1970's. It worked on VHF, the ground stations delivered the received information to “communication nodes” (e.g. Paris for Europe), who distributed it further down to the aircraft operators.

The performance of the link at that time can be stated to be close to “poor”, which had its main reason in the normally low bandwidth of the communication lines used on the ground. As communication technology evolved, the Gatelink was established. In the proceedings of the ATN2006 conference, a contribution covering Gatelink can be found under the header: “Innovative solutions **without** international standardisation”.

CPDLC is now installed both for FANS and ATN equipped aircraft, using the (improved) ACARS/Aircom protocol or VDL Mode 2 [29] (mainly a successor of the ACARS). At present, the data link is operational (both with ACARS and VDL Mode 2) at Maastricht UAC (MUAC) and some European airports. Very detailed specifications exist and are implemented. The clearances provided are currently limited in order to neither increase ATCOs workload nor that of the pilot(s).

Quote from LINK2000+ [30] (entry in the VDR, selection):

> EUROCONTROL and its ATM partners have already demonstrated implementation feasibility of data-link services through pre-operational trial projects such as Preliminary EUROCONTROL Trial on Air/ground Data Link (PETAL II), PROATN, and European Pre-Operational Data-Link Applications (EOLIA). The operational requirements for this first generation of data-link services were defined by the EUROCONTROL ODIAC group.

Presently, further field trials are established at Maastricht UAC in order to define additional clearances suitable for usage with the data link, focusing on human aspects on both sides of the link (ATCO and pilot).

5.2.2 Assessment

LINK2000+ (CPDLC) illustrates the following findings of the study:

- R 9: Install a “Focal Point”,
- F 2: Technical Standards (ICAO) required for Interoperability,
- F 5: Increased Complexity,
- R 5: Prepare for Interoperability,
- R 11: Incremental Implementation.

[29] ICAO Standard available since 2001
[30] LINK2000+ established in 1999 (catching up the results of the pre-programmes)

There are negative aspects however (concerning CPDLC more than LINK2000+):

- Considering the topics addressed (departure clearance and ATIS in the first step), the number of projects started (ref. 5.2.1 quote from LINK2000+) is considered over-sized (meanwhile the situation improved with LINK2000+).
- Progress would have been faster if an agreed ICAO standard for communications (covering both the communication protocol as well as the information to be exchanged) had been established on time (now there are the candidates: ACARS/Aircom, VDL Mode 2, Gatelink, VDL Mode 4).
- Progress is slowed down due to the complexity (changing both the airborne and the ground system synchronously).

It should be possible to define requirements mainly for interoperability, and leave the details to the proprietary solution of the specific vendor (e.g. how the information should be displayed in the cockpit).

A “phased implementation” is considered useful for reduction of risks and enabling operational experience to influence the subsequent steps. As with every new step, the systems on both sides have to be adapted. It will be necessary to plan not too many steps, and to include provisions as part of the equipped systems (both airborne and on the ground) can handle only a subset of the messages already defined.

5.3 ADS-B

5.3.1 Short description of ADS-B

A short look into history shall help to better understand the complexity:

For more than 30 years, the first suggestion was to use SSR Mode S for data link applications supporting surveillance. Message formats and contents (e.g. Down-linked Aircraft Parameters DAP) have been designed and included in the ICAO documentation decades ago. Then the implementation of SSR Mode S was delayed for several years, thus the data link could not be implemented. One reason for the delay may be seen in the lack of (automatically assisted) co-ordination on the ground, which is required to make use of the benefits provided by “Selective” addressing by commanding not to reply to other stations’ interrogations.

In the early 1970th, Inertial Reference Systems started to improve the knowledge of the actual position of the aircraft and indicated it to the pilot. A few years later, GPS solved this in an even less expensive way. Simultaneously the FMS became improved, including the possibility to load a “flight plan route” and calculate it automatically.

With FANS (in the 1980th), these technologies were considered to contribute to the safety of air-traffic by implementing the Required Navigation Performance (RNP), in order to use on-board capabilities also for ATM, fostering the idea of Automatic Dependent Surveillance (ADS).

Starting in 1995, NEAN [31] conducted ADS-B trials using another "innovative" data link: a precursor of VDL Mode 4, utilizing STDMA for the first time in civil avionic applications (the technique had been used (similarly) in military communications (JTIDS in the air-force and LINK16 with the navy). Although using NMEA[32] as a protocol, which is considered to utilize the bandwidth only sub-optimally, it proved feasibility both for the capacity of the link as well as for the data transferred to the ground. The tests included cars on the manoeuvring area of airports, and trials with a dedicated cockpit display (CDTI). It is worth to be noted that the discussion on "how to use the data provided by ADS and what else can be achieved by use of the data link" gained momentum after the NEAN trials; although it was considered a drawback that the technology used (VDL Mode 4) lacked ICAO standardisation. Meanwhile VDL Mode 2 and VDL Mode 4 both became ICAO standards.

At about the same time, the TCAS [33] (later ACAS) became operational. This system uses SSR Mode A squitter (using 1030 / 1090 MHz) to interrogate other aircraft in its vicinity, and to display the received answers in case of danger of a collision on another special display in the cockpit. ACAS became an airborne safety-net function for ATM. Today in case of conflict, the pilot is required to follow the advice of ACAS, and to inform ATC that he deviates from a given clearance by doing so. Meanwhile the implementation of SSR Mode S proceeded, and both the data link capacity of Mode S interrogations and replies as well as the squitter used for ACAS will be used for exchange of data.

A lot of studies handled aspects of how to use the data additionally available, without drawing too much attention off the controller and the pilot from their main task, the safe conduct of flight. This included questions what information to display, are additional display features required or can the information become displayed in existing devices, how pilot and controller have to interact with the system, etc.

Initially, ADS-B transferred aircraft position information to the ground (enhancement of radar information, alternative service in non-radar environments, especially in the vicinity of airports). Currently (together with TIS-B), ADS-B is also investigated for its usability for Airborne Situational Awareness (ASAS), i.e. display in the cockpit of other traffic in the vicinity of an aircraft. One idea followed is to use an "improved ACAS" display, not only to display "conflicting traffic" but all traffic in the vicinity (to assist the pilot in identifying "his" traffic more quickly in a VMC environment). Besides this, ADS-B is considered beneficial for the downlink of "flight plan intend" messages, improving the planning tools on the ground. Presently, ADS-B is considered to be executed via SSR Mode S messages (using 1030 / 1090 MHz). A phased approach is envisaged and an ADS-B Package 1 is defined.

[31] Continued 1999 with NEAN Update Programme I, and 2001 with NEAN Update Programme II
[32] NMEA is the protocol for RS-232 transfer of GPS information between GPS device and a PC, which might be used to display the information on maps. It is and will remain NO ICAO standard.
[33] TCAS first concepts :1956, first implementation: 1987. It's called TCAS in the US and ACAS with ICAO.

The above passages might provide an impression how complex the problems are, and how the ATM community tries to cope with the immense technological changes encountered in the last decades.

5.3.2 Assessment

ADS-B illustrates the following findings of the study:

- F 2: Technical Standards (ICAO) required for Interoperability,
- F 5: Increased Complexity,
- R 11: Incremental Implementation,
- R 10: Install Change Management as early as possible.

SSR Mode S definitions have been years ahead of the existence of the technology itself. This made them partially obsolete [34] when the systems were finally implemented.

The non-existence of an ICAO standard covering VDL Mode 4 hampered worldwide implementation, although the capacity of the link had been successfully demonstrated.

The intermediate success of ACAS using SSR Mode A squitter in air-to-air communication turned the focus of the community back to SSR instead of favouring VDL Mode 4.

In order to handle the complexity of synchronised changes in on-board systems and ground systems, an incremental implementation can be useful.

This may be one of the reasons that the ADS-B Package 1 (covering 5 ground and 7 airborne applications) will rely on SSR Mode S extended squitter instead of selecting VDL Mode 4.

It further provides a good example how fast the knowledge of evolving technology is reflected in additional/new requirements, thus invalidating former R&D results, and causing the development process to start from the beginning.

[34] Communication systems with improved bandwidth available, data from FMS not considered.