AVENUE

An ATM Validation Environment for Use towards EATMS

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1. EXECUTIVE SUMMARY

The objectives of the AVENUE project ("An ATM Validation ENvironment for Use towards EATMS") are:

- the provision of the system architecture of a validation platform, capable of supporting the large-scale demonstration and validation of the EATMS
- the provision of the first instance of that platform hosted at the EUROCONTROL Experimental Centre
- to obtain a wide consensus on the architecture definition within the ATM community.

The 7 key points that cover the work undertaken within the project are as follows:

a) The definition of requirements specific to a validation platform by ATM validation platform users.

b) The definition of a system architecture for validation platforms, independent of any implementation. This entailed the specification of a common set of ATC domain types defined from a logical model (the Data Dictionary) and a comprehensive set of Application Programming Interfaces (APIs) that standardise the definition of methods and events to access these types.

c) The definition of technical infrastructure based on the CORBA3 Component model.

d) The design of the first instance of the platform involving specification of the component interface definitions and a Model of Execution that details the roles, responsibilities and mutual dependencies of each physical component using methods and events defined in the APIs.

e) The adaptation to this architecture of existing ATM components, provided by the 13 partners.

f) The integration of the components at the EUROCONTROL Experimental Centre.

g) A technical exercise which aimed to demonstrate the capability of the developed facility and its suitability for large-scale real-time validation activities.

The AVENUE project has placed in the public domain a set of Application Programming Interfaces (APIs) and an ATC data dictionary defined by consensus of all its stakeholders. The project went on to prove the correctness of an open architecture for validation platforms with a first instance, which was built with more than a dozen existing ATM components provided by key European ATC players around an infrastructure based on CORBA technology. The Technical Exercise successfully demonstrated the capability of the developed facility.

This instance of a platform will constitute a solid basis for large-scale validation activities in the European Commission Fifth Framework Programme, as well as other R&D programmes. The collaboration between European partners to produce a common, flexible and configurable platform will enable essential validation activities to be set up readily and the results from different validation exercises to be compared directly. This will greatly reduce the time required to gain acceptance for a new tool on a European rather than an individual civil aviation authority basis.

Some critical points that arose during this project lead to some lessons learnt, which could be usefully applied to future projects. However, a significant step still remains to be done - to go from the architecture of validation platforms to the architecture of operational systems.

A five-page paper summarising the AVENUE project is available as well as the documentation of the project on the web site http://www.eurocontrol.fr/projects/avenue

2. INTRODUCTION

2.1 Purpose of this document

This document is the Report for Publication of the AVENUE project and is provided as the contractual deliverable D0.8 (part Report for Publication).

2.2 Structure of this document

This document first presents the objective of the project, describing the background and project objectives and identifying the members of the consortium that worked on the AVENUE project. Next, the document summarises the means used to achieve the objectives.

The document then provides a scientific and technical description of the project, presenting the work breakdown structure. It provides a summary of the work performed by work package, and proceeds to present the detailed results achieved by the AVENUE project by work package.

The document presents a series of conclusions regarding the AVENUE project, in particular the lessons learnt.

In an appendix is given a résumé of the deliverables.

2.3 Intended audience

This document is publicly available.

2.4 Responsibilities

This report for publication was compiled from the contributions of the WP managers.

3. OBJECTIVES OF THE PROJECT

3.1 Project background

As everybody knows the situation in Air Traffic Management (ATM) is not at its best. Is it possible to cope indefinitely with an ever-increasing traffic demand? The objectives of the ATM system are numerous (capacity, punctuality, safety, cost, environmental protection), as are the non convergent interests of the actors in this field (ATM and aeronautics industries, airlines, ATS providers, pilots and controllers, governments, passengers, citizens…). Whereas little progress is expected from existing systems and classical improvement methods in the medium term, uncertainties remain over the efficiency of the new technologies. There is not a single concept or function or system (free route, autonomous aircraft, D/L, ATN, MODE/S…) which is accepted by everybody as a serious improvement to capacity, efficiency, safety. As regards the technical, operational or cost benefit points of view, nothing has really been demonstrated.

Deficiencies are observed in the existing ATM systems and operations:

- poor interoperability between systems and incomplete sharing of data induce ATM system inefficiencies (from a pan-European perspective), additional costs for ATS providers (procurement, maintenance, controller training) and difficulties for manufacturers[1],
- slowness in introducing new concepts and new technologies: too much time is needed before the results of R&D are implemented, and there is only limited co-operation between R&D and Industry. There is also little reusability and slow acceptance of new procedures.

To try to speed up the definition and introduction of the next generation European ATM system, the European Commission (EC) and ATM community have identified the need for the key ATM players to develop a more detailed **common** understanding of issues and solutions, a definition of **common** requirements and a **joint** commitment to development plans for validation activities (Figure 3-1).

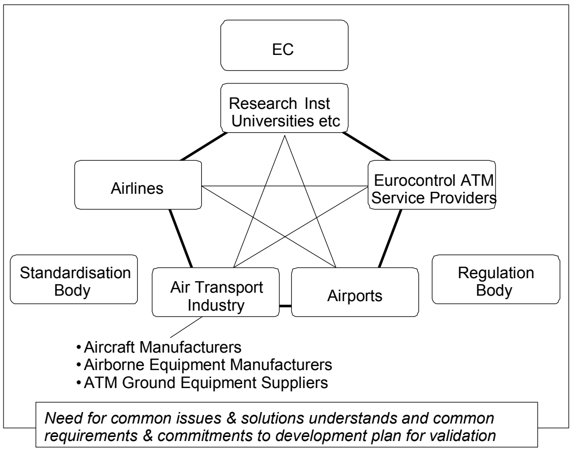

Figure 3-1

[1] "Investment decisions in the past often have been taken on the basis *of national industrial interests* with the result that the centres have limited technical or operational compatibility with their neighbours, or low interoperability. This insufficient interoperability results in a multitude of severe inefficiencies and additional costs, ranging from fragmented controller training, through to increased procurement and maintenance costs, and to major difficulties in operational co-ordination. The small size and the predominance of national standards developed between the service providers and the national industry has led to fragmentation of the equipment market which does not facilitate the necessary industrial co-operation to develop common standards, in particular for new technology (e.g. electronic flight strips, medium-term conflict detection tools, flight data processing). (…) The development and implementation of *new technology* in control centres is unnecessarily difficult even if this technology is available elsewhere. Training for the introduction of new technology into control centres could also be improved. Without a dramatic change in this situation, it will be a real challenge to introduce the technologies that are required to increase capacity." (EC Single sky HLG report)

In their recent Single Sky report, the EC suggests a new partnership approach: production and validation of common operational requirements by ATS providers and increased industrial involvement to develop European **standards** which will ease both the R&D activities and operational improvements.

It is in this spirit that the 4th and 5th Framework Programmes of the Commission have been established to develop and promote **standardisation** and **validation** activities with a constructive and **consensual** involvement of all stakeholders[2]. It is clear that the pursuit of common solutions is difficult as it calls into question cultural, strategic and managerial behaviours.

The 4th FP (1994-1998), planned to act as a catalyst for implementation, was designed as a "definition phase" and a vast amount of tasks were identified, in a wide variety of sub-areas, to identify requirements, concepts, functions and technical enablers for ATM, airports, CNS and safety. In the 5th FP, the EC wanted to speed up the implementation of the new ATM-CNS systems by further development, integration and validation of concepts, systems and technologies, pre-operational tests and progress towards certification. The time horizon is 2005 onwards. The overall objective of the 5th FP for ATM is **to validate a European gate-to-gate ATM/CNS system**.

One of the tasks of the 5th FP (called "operational platform for a European ATM system in the medium time frame (2005-2010)") was dedicated to initialising the Validation Platform for the ground segment based on previous work and complementary to the airborne ATM technology platform developed in the Aeronautics Key action. The most promising ATM and CNS elements previously developed in European, national or other (industry, research) organisations would be integrated and validated, together with new operational procedures and methods, in order to make recommendations for standardisation and implementation.

3.2 Project objectives

The AVENUE project ("An ATM Validation ENvironment for Use towards EATMS"), the cornerstone between the two FPs, uses previously validated inputs from the Commission, Eurocontrol and national projects throughout Europe and builds the basis of this validation platform. Its main objectives were:

- **the provision of the system architecture of a validation platform** capable of supporting the large-scale demonstration and validation initiatives of the European Commission, Eurocontrol and all others concerned with validation of the EATMS,
- **the provision of the first instance of that platform**, hosted at the Eurocontrol Experimental Centre, Brétigny, demonstrating the architecture and allowing early validation exercises. This development is based on the adaptation to the defined architecture of a selection of CNS/ATM components representative of the state of the art developments in Europe and on an infrastructure based on CORBA technologies,
- **to obtain a wide consensus** in the architecture definition and platform development within the ATM Community.

In this project, there was **no validation of any concept or system** but a demonstration that the architecture works, the adaptation of components is feasible and that the instance is usable for early validation exercises.

Besides validation services (data preparation, test preparation, supervision, configuration management, recording, data analysis) the platform would be capable of integrating any representative ATM components. The platform would be an open, flexible and modular "environment" which enables evolution, integration, interoperability and growth. This flexibility can only be obtained through an architecture common to all instances of the platform and independent of the components which are plugged into it. It leads to agreed

[2] "In order to increase capacity, it is necessary to implement new concepts, tools and procedures in the next few years. This is a relatively small market, development processes are complex and there are limited resources in Europe. Therefore a new partnership approach is required which allows a balanced involvement of all stakeholders, stimulating creativity and the sharing of knowledge, experience and risks. This process could be achieved by:
- Enhanced co-operation between research and development organisations and ATM industry in order to pool resource and minimise duplication.
- Consolidated technical and operational requirements across Europe in accordance with Community legislation.
- A European approach to the validation of new systems against defined requirements." (EC Single sky HLG report)

"de-facto" system standards, which permit the exchange of components at a software level and direct comparisons of results.

Note that the project did not intent to define standards for operational system architectures.

3.3 Means used to achieve the objectives

The AVENUE project had some fundamental differences from the many other projects that have had the objective of building an ATM simulator for validation purposes. The majority of such projects have had a specific operational concept together with defined components to realise the concept. The work of these projects has concentrated on connecting the components together in a specific configuration.

The major difference with AVENUE is that we intended to define a flexible and evolving ATM architecture which could welcome any operational concepts through appropriate components. In this project, there was no validation of any concept or system.

The architecture was based on the definition of a comprehensive set of Application Programming Interfaces (API), using Eurocontrol PHARE (CMS) and EC PATIO as starting points.

Industry standard CORBA technology using technical services from the PATIO unified architecture and EUROCONTROL's OASIS were selected by the EC as the middleware foundation for the platform.

To demonstrate this architecture, AVENUE has integrated a wide range of existing components from both research (EC funded, Eurocontrol, Research centre activities) and industry. These components have been chosen by the EC to represent a comprehensive set of the ATM facilities considered necessary for validating future EATMS concepts. These components have been adapted to the defined AVENUE architecture (rather than the architecture being created to accept the existing components).

The components that were selected initially for integration were the following (note that not all of them have been integrated):

COMPONENT NAME	COMPANY	FUNCTION
EONS	EEC	CWP
ARTAS	EEC	Surveillance Data Processing
IPAS	EEC	Environmental Static Data Processing Flight Plan Preparation Data analysis
ATG	EEC - NLR	Air traffic generator
CINCAT/FPM	NLR	ATC tools: monitoring aids: Flight Path Monitor
Airborne Platform (ECS)	DERA	A/C simulator: Multi-cockpit ATM platform synthetic environment
SACTA FDPS	AENA/INDRA	FDPS
CINCAT-CP	AIRSYS ATM SA	ATC tools: conflict detection: conflict probe
CINCAT-TP	AIRSYS ATM SA	ATC tools/FDP: trajectory prediction
ASAS	NLR	Airborne Separation Assurance capability
EOLIA – CPDLC	AIRSYS ATM SA - SOFREAVIA	CNS: datalink communications CPDLC
EOLIA – FLIPCY	AIRSYS ATM SA	CNS: air and ground flight plan consistency
EOLIA-DLIC	AIRSYS ATM SA	CNS: Data link initiation capability
EOLIA – ADS	AIRSYS ATM SA	CNS: ADS for non radar environment
SIMINGA	SOFREAVIA	Simulator interconnection
FARAWAY AS	ALENIA	ADS-B processing Radar & ADS-B data fusion
FARAWAY EVA	ALENIA	AS performance data analysis
OASYS	AIRSYS ATM LTD	Operational supervision
OASIS	EEC	CORBA based middleware
ARISTOTE	ALCATEL-ISR	Data analysis
ARCADES	ALCATEL-ISR	Recording
JANE interoperability	DFS	Connection to JANE platform

Table 3-1: List of selected components

Remarks:

1. An audit was carried out after one year to see:

- if the first results (requirements, architecture) were satisfactory, in particular with regard to the openness and flexibility of the platform
- if the scope of the first instance covered the essential functions or services needed for such a validation platform, without any unnecessary overlaps,
- if the adaptation strategy for the components and also the middleware were acceptable:
  - when adapted, the components were to provide a level of integration compatible with the requirements and inline with the architecture approach,
  - the adaptations were feasible in the frame of the existing planning and budget and also the associated risks were acceptable to the project.

2. In order to demonstrate further the flexibility of the platform (beyond integrating components from multiple sources, R&D, industry etc., which shows flexibility of the architecture), it would have been beneficial to integrate and test more than one instance of some key AVENUE components (e.g. the FDPS, CWP). This has been done for the TP (using a TP from INDRA) and the traffic generator (using the ATG from CENA instead of the EUROCONTROL ATG), although this was not the original objective (see Table 3-1 for a list of the selected components). Parallel activities to the project have been carried out by some partners to demonstrate further the flexibility (e.g. by replacing the FDP) (see chapter 6).

3.4 Consortium structure

The consortium that carried out the project was made up of the following members, all principal contractors:

AENA (Spain)

AEROSPATIALE (France)

AIRSYS ATM LTD (UK)

AIRSYS ATM SA (France)

ISR (France)

AMS (Italy)

DERA (UK)

DFS (Germany)

EEC

INDRA (Spain)

ISDEFE (Spain)

NLR (The Netherlands)

SOFREAVIA (Co-ordinator) (France)

<u>WP leaders:</u>

WP0 (Co-ordination): SOFREAVIA

WP1 (Requirements): ISDEFE

WP2 (Architecture): AIRSYS ATM SA

WP3 (Adaptation): INDRA

WP4 (Integration): DFS

WP5 (Exercise): DERA

3.5 Deliverables

The following is a list of technical deliverables produced within the project and put into the public domain:

Ref	Title
D1.1	Consolidated Requirements Document
D2.1	SSS System/Subsystem Specification
D2.2	SSDD System/subsystem design Description (part 1 : generic and part 2 : first instance)
D2.3	IRS Interface Requirements Specification
D2.4	SUM of common tools
D2.5	IDL packages
D2.6	Software packages
D3.1	Component Description Documents
D4.1	Test & Integration Master Plan
D4.2	Configuration Management Plan
D4.3	Platform Technical Documentation
D5.1	Technical exercise Strategy Plan
D5.2	User guide (included in D4.3)
D5.3	Technical Exercise Report

Table 3.2: AVENUE Technical Deliverables

A résumé of each deliverable is provided at the end of this document.

4. SCIENTIFIC AND TECHNICAL DESCRIPTION OF THE PROJECT

4.1 Key points

The key points of the project are:

a) The **definition of requirements** specific to a validation platform by ATM validation platform users, but noting in particular:

- The AVENUE platform not only aims to integrate EATMS concepts but also to support the facilities which are necessary for their validation. The requirements do not cover specific ATM functions but validation functions.
- The first instance of the AVENUE platform was never intended to fulfil completely all the requirements: conformance to the requirements will be spread over further developments of the validation platform.

b) The **definition of a system architecture** for validation platforms independent of any implementation (i.e. the generic part):

- Definition of the logical model that provides the validation platform scope, its logical organisation and granularity.
- Specification of a common set of ATC domain types defined from the logical model (the Data Dictionary) and a comprehensive set of Application Programming Interfaces (APIs) described in the formal language IDL that standardise the definition of methods and events to access these types ("what" not "how").

It is of paramount importance that the API specifications are defined without reference to either the components or the middleware technology. Two different approaches have to be considered simultaneously : top down for the generality and bottom up to take into account the experience gained in the definition and development of the components.

c) The **definition of the technical infrastructure** based on the CORBA3 Component model to offer generic services that do not deal with the semantic contents of the data being manipulated.

This infrastructure augments the capabilities provided by CORBA and provides access to the capabilities of the middleware in a clear, regular, consistent and controlled manner. Each component is encapsulated in a "container" that isolates it from the other components and from the middleware. All the technical details, such as how to locate the other components, are isolated from the component and managed at the container level.

d) The **design of the first instance** involving specification of the component interface definitions (in IDL) and a Model of Execution that details the roles, responsibilities and mutual dependencies of each physical component in the first instance of the AVENUE platform using methods and events defined in the APIs.

The flexibility of the platform is enhanced by providing a code generation environment for the developers of the platform. This code generation environment also provides an additional level of syntactic checking of the various specifications (APIs and Component definitions) that formally describes an instance of the platform.

The design of the first instance includes also the physical architecture of the platform distributed between more than 30 computers and with a connection to an adjacent platform, for distributed simulations.

e) The **adaptation of the components** to this architecture.

f) The **integration of the components** at Eurocontrol Experimental Centre, according to a staggered plan.

g) The **technical exercise** which aimed to demonstrate the capability of the developed facility and its suitability for large-scale real-time validation activities.

4.2 Work Packages and life cycle

Five main Work Packages have been identified in the AVENUE project, plus WP0 that was related to the Project Co-ordination and Technical Management (which will not be described in this document). The following picture gives the V-cycle of the project and the main documents produced.

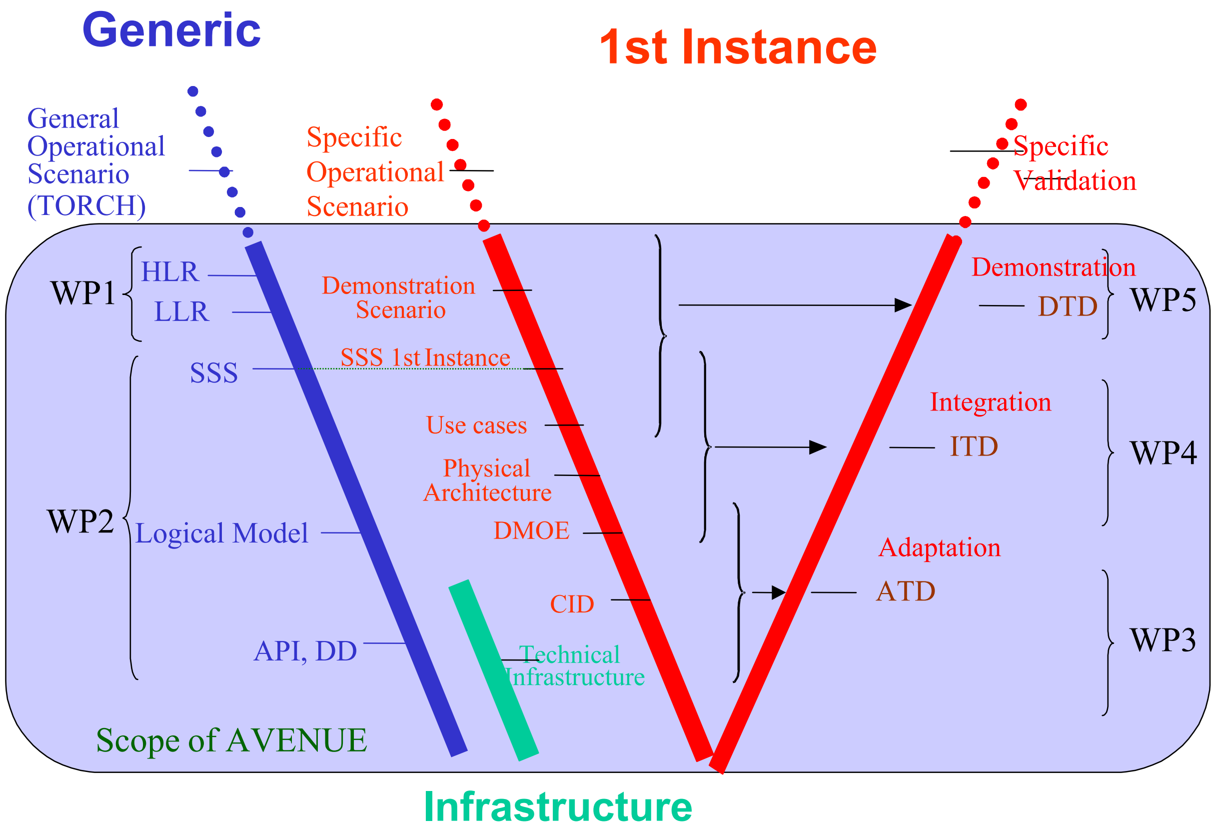

Figure 4-1: Life Cycle of AVENUE

WP1: Requirements

WP2: Architecture

WP3: Adaptation

WP4: Integration

WP5: demonstration

HLR: High Level Requirements

LLR: Low Level Requirements

SSS: System Sub-system Specification

API: application Programming Interfaces

DD: Data Dictionary

DMoE: Dynamic Model of Execution

CID: Component Interface Definition

ATD: Adaptation Test Description

ITD: Integration Test Description

DTD: Demonstration Test Description

4.3 WP1: Platform requirements

4.3.1 Link with the key points listed in 4.1

WP1 covered key point a and participated in key points d (use cases for the dynamic model of execution) and g (the technical exercise).

4.3.2 Objectives

To ensure that the validation platform would meet the needs of the customer – i.e. not only DGVII but also the wider ATM user community concerned with EATMS validation – it was necessary to specify clearly the **requirements** that the platform must meet. These requirements have to cover what the validation platform will be used for, how it will be used, how the results of the platform will be generated and analysed and what the results will be used for.

The objective of Work Package 1 was to provide requirements for the validation platform in terms of operational requirements (capability, performance, reliability) and in terms of validation services, but not in terms of functional requirements depending on an operational concept.

NB : One must always have in mind that the aim was not to define one platform for a specific ATM configuration but to define a flexible and evolvable architecture capable of supporting many instances of the platform corresponding to families of specific requirements.

The provision of data recording and playback facilities had to be addressed, as well as the necessary requirements for planning the validation exercise, preparing the data and the tests, supervising the system, analysing the recorded data and reporting the results.

It was planned to successively break down these requirements: the High Level Requirements being refined to generate Low Level requirements. Initially, the user view was given. At the end of the Work Package, the requirements had been translated into a developer view which was more appropriate for the design of the platform.

Another objective of this Work Package was to provide a specification for the technical demonstration exercise. The work package also assisted in the definition of use cases, which are one part of the platform's dynamic model of execution.

4.3.3 Results

4.3.3.1 Requirements

4.3.3.1.1 Methodology

The global methodology followed to define the AVENUE Requirements is represented in Figure 4-2.

First, the "high level" requirements and expectations were identified through an initial consultation exercise in co-ordination with the EC CAVA concerted action. This consultation exercise defined the goal of the platform by answering the questions:

- For whom will the platform bring added value?
- What is required to achieve this added value?
- What is required to ensure successful evolution of the initial instance of the platform?

Having specified such "high-level" requirements, further "low-level" requirements were developed. Such low-level requirements are typified through defining:

- The services to be offered by the validation platform;

- The overall methodology to be employed in the execution of validation exercises conducted on the platform.

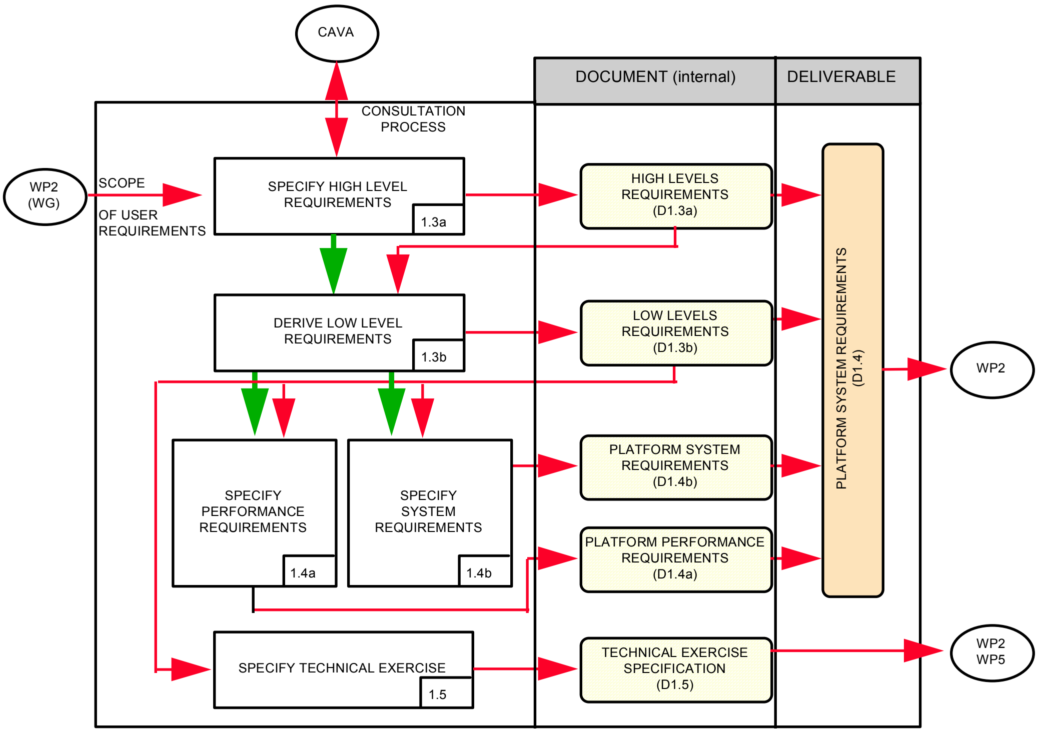

Figure 4-2:- WP1 global methodology

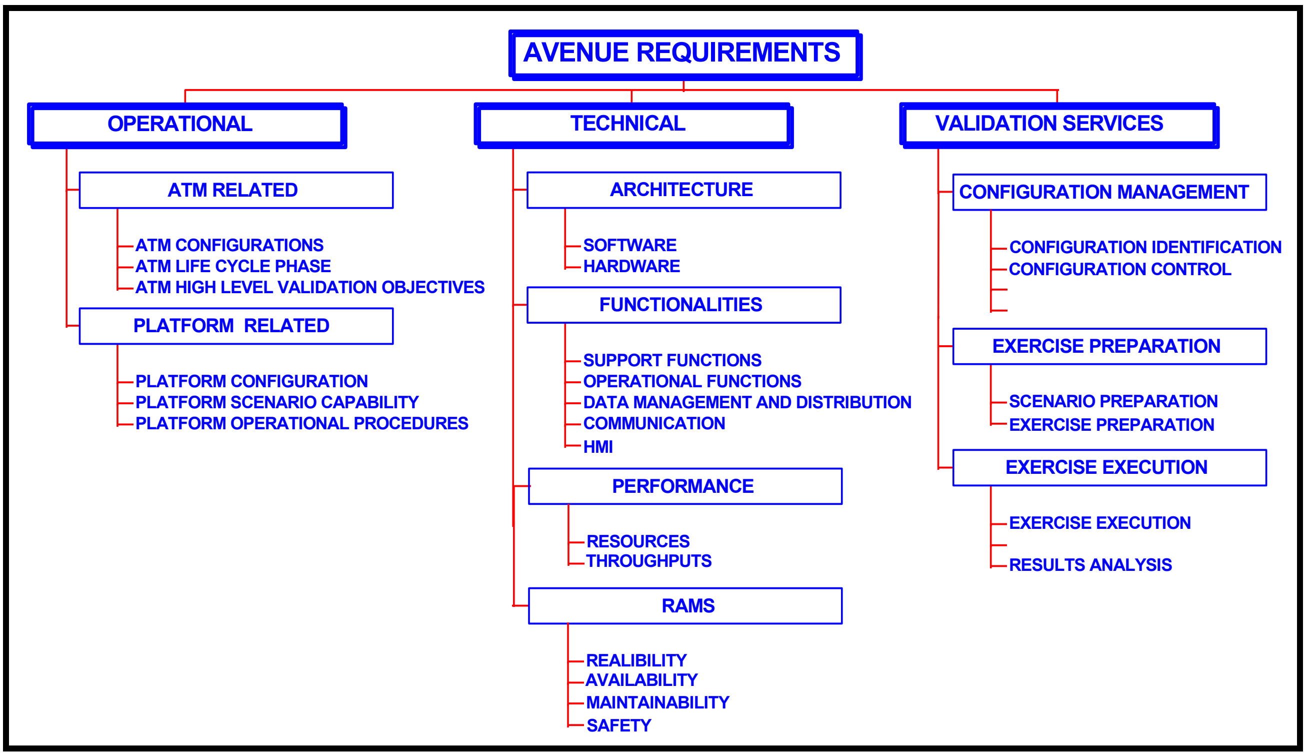

Figure 4-3: Structure of the user requirements

By examining the high-level and low-level requirements, a number of platform performance and system requirements were further developed, e.g. :

1. Platform Performance Requirements :
   - specification of required inputs and outputs
   - specification of performance analysis techniques
   - specification of acceptance criteria
2. Platform System Requirements:
   - specification of system performance (e.g. response time must be less that one second)
   - specification of system architecture

These Requirements were defined, as much as possible, independent of the current ATM components and mainly focusing on the extended use of the platform at least for short and medium term time-frame.

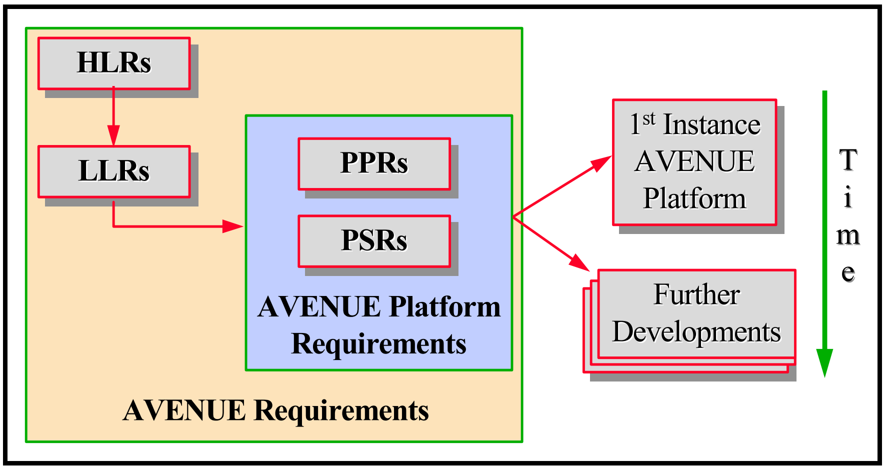

Figure 4-4: Requirements Conformance

Again, these requirements are exclusively for the AVENUE platform. They are not intended to be the requirements for an overall EATMS validation platform. The target of the requirements is only the platform, not the EATMS concept itself. The AVENUE Platform Requirements can thus be seen as a subset of the overall requirements for an EATMS validation platform.

4.3.3.1.2 Results

The following overall results have been obtained:

- A methodology based on a top-down approach has been developed, in order to define, extract and derive requirements on the basis of the expectations expressed by the platform users and stakeholders. This methodology provides for subsequent reviews and updates of the requirements.
- A procedure has been defined to ensure the traceability of the requirements defined. This will facilitate the future management of changes or revisions of the requirements, identifying the impact of the changes on other requirements and ensuring the consistency of the overall set of requirements.
- A structure has been specified for platform requirements from the perspectives of both the platform user and the platform developer. This structure enables the orderly classification of the requirements derived/extracted.

- A database has been specified, designed and developed using a commercial tool. This database will be used for the recording and configuration management of all of the requirements identified.
- A lifecycle for the ATM system has been proposed, whose objective is to define the scope of the validation of the platform for all of the phases of the ATM lifecycle.

The requirements identified cover a broad spectrum, ranging from requirements for ATM components and configurations, to requirements for the operation and exploitation of the platform.

The User Requirements have been established for a time horizon up to the year 2015. For this reason, some of the requirements are to some extent generic, since it is impossible at the present time to determine the specific configurations and/or components for the ATM system of the future. These requirements will have to be revised and updated, in order to determine the specific requirements for the platform related the ATM configuration at any given time.

The Platform Requirements (those defined from the platform developer's perspective) are oriented toward a specific platform, of which AVENUE will be the first instantiation. These requirements have been derived directly from the User Requirements.

Several observations can be made regarding the scope and granularity of the requirements, as follows:

- The requirements have been specified and approved (as fundamental requirements which may evolve and develop in the future) by a representative set of future users of the platform (e.g., service providers, research centres, industrial organisations).
- The granularity of the requirements is not homogeneous, because, as was discussed above, some of the requirements cannot be stated in great detail except for specific configurations of the ATM system to be validated.
- The coverage of the requirements is considered to be sufficient and complete, given the diversity of areas addressed.
- The distribution of the requirements across the various areas is fairly balanced. A representative number of requirements has been identified in each group.

The requirements identified should not be considered a closed set. Provision must be made for periodic review and expansion of the requirements, on the basis of the following factors:

- Technological and methodological evolution in the field of validation,
- Future design and development of the ATM system and its specific components.

4.3.3.2 Technical exercise specification

Finally, the specification for a Technical Demonstration of the platform, to be conducted under WP5, was developed. The Work Package assisted in the definition of use cases which were inputs for the Dynamic model of execution of the first instance and for the definition of the Technical exercise.

4.3.3.2.1 Main characteristics

Using the stated objectives above, it is possible to distil out the following main characteristics of the platform together with the implications for the first instance:

- The capability to carry out validation of ATM systems and concepts. This means that the first instance must include a core set of validation facilities and tools.
- The flexibility to configure and evolve an ATM architecture which will support the integration of a range of different ATM components in successive instances of the platform. The first instance will provide evidence on how easy or otherwise it will be to adapt components to the architecture. It will also show flexibility in the sense of how the same components can be applied to different ATM procedures.
- The capability to support large-scale demonstrations. The first instance will provide evidence on performance and scalability for validation experiments in the Fifth Framework

4.3.3.2.2 Demonstrations

It is now possible to define a set of demonstrations, that will meet the characteristics and hence the overall objectives:

- **Configuration**: showing that the platform supports the core facilities for validation experiments, together with the ATM functions provided by the components of the first instance.
- **Flexibility**: showing that components can be adapted to the architecture, as well as be applied to different types of airspace and ATM procedures.
- **Scalability**: showing that the platform performance can support large-scale exercises, by handling an increased number of working positions and amounts of traffic as well as showing interoperability with other sub-systems (such as JANE).

The following deliverables have been produced by WP1:

- D1.4: Consolidated Requirement Document (external document)
- T1.5: Technical Exercise Specification (internal document)

4.4 WP2: Platform architecture

4.4.1 Link with the key points listed in 4.1

WP2 covered key points b, c and d.

4.4.2 Objectives

Having defined the requirements for the validation platform, it was then possible to design a **system architecture** for a validation platform and furtherto describe a specific architecture that meets the requirements for the first instance of this platform.

Basically, this task was carried out in two stages:

- Definition of a **logical architecture**, independent of implementation details. The resulting architecture would fulfil the requirements expressed in WP1 as well as the main project objectives: to have an open, flexible and modular validation environment to make easier:
  - addition of new components,
  - replacement of components,
  - dissemination to a wide variety of validation sites.
- Design of a **physical architecture** for a specific instance of the platform, the first instance, which partially meets the logical architecture - i.e. an implementation of the logical architecture, covering a pre-defined operational scenario, on the basis of existing software tools and infrastructure.

  At this stage, infrastructure and components that had to be adapted to meet AVENUE requirements were clearly identified. Also, the static and dynamic Models of Execution of the platform were described.

4.4.3 Results

Four main activities were conducted within WP2:

1. Specification of the platform with the refinement of WP1 requirements, in particular the functional requirements.
2. Definition of the logical architecture (i.e. logical model = generic platform) by:
   - producing a system logical design, also called the ***logical model***. It describes in functional terms the AVENUE platform based on the decomposition into modules of existing ATC systems, enhanced

with foreseen ATC functionality. Each module is described with regards to the specific function(s) it covers and the interaction with other modules (i.e. data flows).

- defining, from the logical model, standard ATC domain interfaces between the logical modules, called ***APIs*** - Application Programming Interfaces. This involved the definition of a set of standard ATC domain types to be exchanged between the modules, called the ***Data Dictionary*** and the definition of a set of services (methods and events) to access these types.

  When implemented the APIs represent the standard way in which an AVENUE component interfaces with the other AVENUE platform components (a component being the implementation of one or more logical modules).

3. Design of the ***infrastructure*** with the definition of Quality of Service (QoS) and implementation rules (this involved the improvement of existing OASIS middleware using CORBA3 technologies).
4. Design of the physical architecture for the first instance, including refinement of the infrastructure.

During the first three activities, components and the underlying middleware were treated independently of any implementation, including the first instance of the platform. The definition of the logical architecture re-used the results of previous EUROCONTROL and EC projects (e.g. EATCHIP, PHARE, PATIO, FARADEX, CINCAT) and merged these with industrial developments.

Figure 4-5 summarises the link between the activities and resulting deliverables from WP2.

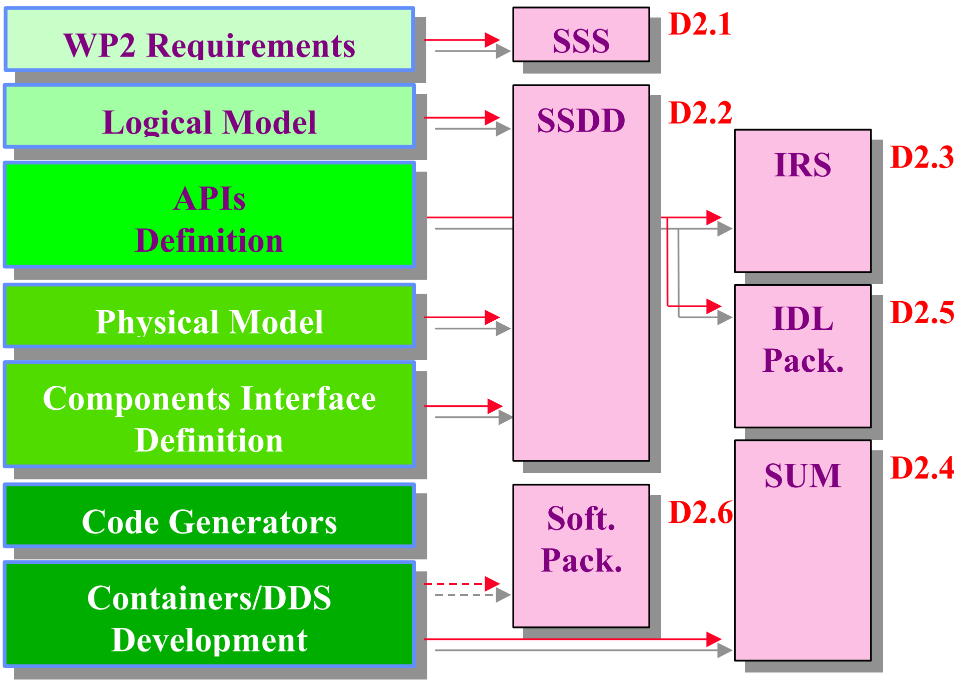

Figure 4-5: Work Package 2 activities with deliverables

- ***D2.1 - SSS - System/Subsystem Specification***

The specification of the platform results in the SSS document. The SSS specifies the AVENUE system requirements. These have been derived from the Low Level Requirements (LLR) produced in WP1.3, with which there is traceability.

- ***D2.2 - SSDD - System Sub-system Design Document***

The SSDD collects all information related to the design of the platform. The document is divided into two parts:

- part 1 of the SSDD deals with the *generic aspects* (implementation independent) of the system architecture.
  - The *System Wide Design Decisions* document details the fundamental design structures that have dictated the specification of the AVENUE software architecture. It gives an overview of the main design choices.
  - The System Logical Design (also called the *Logical Model*) describes the AVENUE platform in functional terms. This is based on the decomposition of existing ATC systems into modules, enhanced with foreseen ATC functionality. Each module is described with regards to the specific function(s) it covers and the interactions with other module (i.e. data flows).
- Part 2 of the SSDD deals with the *architecture of the first instance*. It describes the design of the first instance platform in terms of it's physical elements and the mapping of the software onto the hardware. It was derived from the logical model and logical architecture by performing a decomposition of the system into components based on the following factors: abstraction, information hiding, hierarchy, and modularity.

  In transforming the logical model to the system design of a platform instance, some decisions were made in which capabilities and interfaces were allocated to particular components.

- ***D2.3 - IRS - Interface Requirement Specifications &***
  D2.5 - IDL Package

APIs result from the logical model and therefore remains independent of any implementation of the platform. They represent standard ATC domain interfaces between logical modules.

The API specification consisted of the definition of:

- A Data Dictionary, which is a set of standard ATC domain types to be exchanged between the modules,
- A set of services (methods and events) to access these types.

Note: When implemented the APIs represent the standard way in which an AVENUE component interfaces with the other AVENUE platform components (a component being the implementation of one or more logical modules).

The APIs have been written in IDL– (Interface Definition Language) organised as a set of IDL files (deliverable D2.5). The IRS (D2.3) is the associated documentation that gives a more complete description of the types and services. An API Style Guide which is part of the IRS describes the rules that supported the API definition.

- ***D2.4 - SUM - Software User's Manuel***

The development of the infrastructure results in a set of user guides that describes the infrastructure and implementation rules. As follows:

- *Design Centre Definition*: major design centres that form the basis of the AVENUE technical infrastructure.
- *Component Adapter's Guides*: support for adaptation of the components to the first instance.

- *Data Model User Guide*: description of the data model product and user guide.
- *Avenue Infrastructure Installation Guide*: support for the installation of the AVENUE Infrastructure product.
- *Infrastructure Platform User Guide*: Support for the administration of the Infrastructure platform.
- OASIS Software User's Manual for use with AVENUE Middleware.
- PLUG Software User's Manual (under licence).

- ***D2.6 – Software packages***

This deliverable refers to a collection of software resulting from the infrastructure implementation:

- OASIS middleware (under licence)
- PLUG runtime (under licence)
- CID (Component Interface definition).

4.5 WP3: Component adaptation

4.5.1 Link with the key points listed in 4.1

WP3 covered key point e but also the improvements of key points b, c, d which were found necessary during the adaptation of the components.

4.5.2 Objectives

The work under this Work Package consisted of the adaptation of the selected components so that they could be integrated on the platform. This involved modifying the components so that they were compliant with the architecture and the interfaces defined in WP2. It also included unit testing of these adapted components.

Therefore, the major activity was adaptation of components rather than development.

Considering the WP2 outputs, the objective of the WP3 was to perform the necessary adaptations in order that each existing component becomes an AVENUE Component, that is:

- It provides the allocated functionality according the requirements (SSS)
- It complies with the specified CID and model of execution defined for the first instance
- It fits into the technical infrastructure.

4.5.3 Results

The following is the list of components successfully adapted to the defined architecture:

Component Identifier	Function
ARCADES	Data recording
IAS	Air Surveillance Gateway
ASAS (adapted, but only integrated locally to ECS)	Airborne Separation assurance
CINCAT/CP	Conflict probe
CINCAT/TP	Trajectory predictor
EOLIA/CPDLC-DLIC	Ground part of the Controller-Pilot datalink.
EONS	Controller working position
IPAS and Data Servers	Data preparation off-line plus the on-line servers ACR, ASP, FPG(Aircraft, Airspace, Flights)

JANE interoperability	Interoperation between AVENUE and JANE platforms.
MASS	Air traffic generator, including the air part of the CPDLC
OASIS	CORBA based middleware
Radar Emulator	Emulator of Radar plots from MASS air traffic data
SACTA/FDPS	Flight Data processing and distribution.
SACTA/TP	Trajectory predictor (Adapted only to facilitate platform testing)
SIMINGA	Simulators interconnection gateway.

A Component Adaptation Document (D3.1) has been produced for each component that was integrated at the end of the project. These documents are intended to be part of the documentation package available from the project to support further adaptation activities, for different components, by other partners or for different instances of the architecture. As such, the documents do not contain an internal design description of the component but a general overview, the documents also contain a description of the adaptation process performed and the CID defined, and the test procedures and results obtained during the local testing of the component.

4.6 WP4: Integration

4.6.1 *Link with the key points listed in 4.1.1*

WP4 covered key point f.

4.6.2 *Objectives*

The objectives of this Work Package were

- *to integrate progressively the components adapted in WP3 into the first instance of the platform, for which the architecture was defined in WP2,*
- *to perform appropriate technical and functional testing to verify the success of the integration,*
- *and to make the resulting platform available to WP5 to perform its Technical Exercise*

The **integration** of the components was conducted at the EUROCONTROL Experimental Centre at Brétigny.

4.6.3 *Results*

The integration of components:

Three modes of integration of components were foreseen:

- *Full integration, or "white-box approach". This is the standard way of integrating AVENUE Compliant Components into the platform, and it is the case for almost all the components of the first instance shown in the figure below.*
- *Stand-alone component, or "black-box approach". A stand-alone component is integrated through a Gateway that dialogues with the component using its protocols and links, but implements the AVENUE APIs and DD in such a way that the rest of platform components see it as fully integrated. This was the case for ARTAS firstand the JANE platform (external complete platform) in the first instance.*
- *External components/systems, or "grey box approach".- An intermediate method which is suitable for the connection of external entities to the platform. This was the case in the first instance of MASS (air part) and the JANE platform gateway.*

The components that were available to the integration team are listed above. Although delivery of components to the integration site was in several cases delayed (the longest delay being eight months) the integration lead to the following result:

- *12 white-box components, adapted to an agreed DD & architecture, from different sources were interoperating on a common infrastructure*
- *plus 4 black-box (ADSP/ARTAS/Data Fusion/JANE) and 2 grey-box components (JANE gateway/MASS-SOF)*
- *the integration therefore resulted in the core part of an ATM Validation platform plus limited data link functionality*
- *in addition, the project produced the first connection of two different ATM platforms, allowing for distributed simulations*

In summary, the integration resulted in the following platform structure:

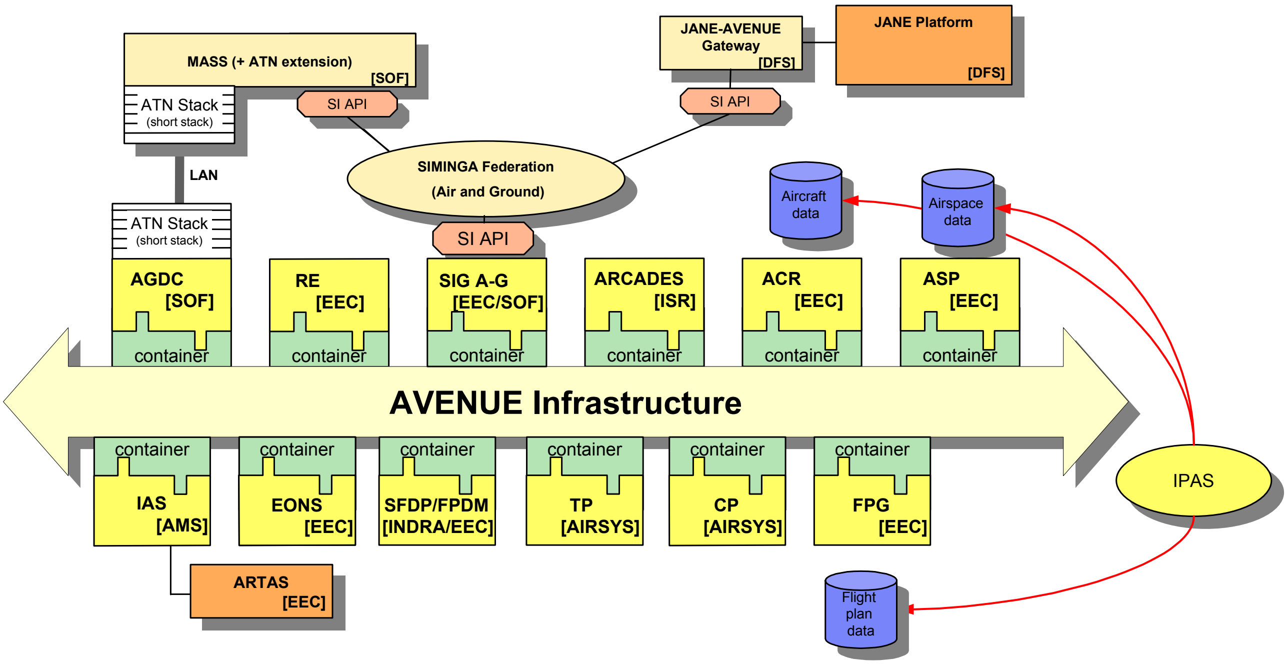

Figure 4-6: Final Structure of AVENUE Platform

The following components were not integrated:

- *FLIPCY, ADS-C*
- *ADS-B, data fusion ,*
- *ECS (and thus ASAS, although this was integrated locally into the ECS)*
- *FPM*
- *ARISTOTE (but replaced by a 'formatted dump' tool)*

<u>Change management and configuration control</u>

The change management process for the project was defined within the initial stage of the WP. MDRs (Modification or Defect Reports) could be issued by any person involved in the project, and were submitted to the process handled by a Change Control Board (CCB). The composition of the CCB depended on the nature and subject of the MDR, problems were first handled at a technical level by the Design Team. If a solution could not be agreed in this forum the project Technical Management Cell took over and if the problem could not be resolved by this group then the Project Co-ordinating committee (comprising of representatives of all AVENUE partners) would make the decision. This enabled fast resolution of “easy” technical problems that could be handled directly by the technical experts. The change management process was performed via a tool provided by EEC, Remedy, which is used by a number of other projects for change control.

A total of 201 modification or defect reports had been raised during the adaptation/integration of the platform. At the end of the project, none of these were “open” or “in work” any more, all were either “closed” (=corrected and implemented) or “deferred” (to be coped with in a future project).

Configuration Control was based on the Continuus/CM tool which is currently in use for a number of projects at the EEC. Development of distributed software and exchange between different sites requires the use of a common configuration management tool to reduce the risk of inconsistencies etc. The centre has developed significant expertise in the use of Continuus, and has instituted a local support team for the product. For this reason this configuration tool was chosen for the AVENUE project. The tool supports the use of distributed databases with manual or automatic synchronisation, which also detects conflicts between the local and remote versions.

Deliverables:

Three deliverables have been produced by this work package:

- *The Test And Integration Master Plan: this document describes the integration methodology, specifies the integration steps and sub-steps, specifies general descriptions for technical and functional integration tests, and details the requirements traceability.*
- *A Configuration Management Document: documentation describing the software configuration and the change management process, the applications used, and their operation by a user.*
- *The Site and Platform User Guide: documentation for a partner interested in using the AVENUE platform, i.e. contact information, configuration details, definition of an exercise, the machines and applications hosted.*

4.7 WP5: Technical exercise

4.7.1 Link with the key points listed in 4.1

WP5 covered key point g (technical exercise) and participated to key point f (Use Cases for the dynamic model of execution) .

4.7.2 Objectives

The objective of the Technical Exercise was stated in the Technical Annex as “to demonstrate the capability of the developed facility and its suitability for large-scale real-time validation activities in the Fifth Framework”.

4.7.3 Results

The most significant result of WP5 was the success of the Technical Exercise, with the customer able to witness a real-time simulation of an ATM system comprising 5 sectors with 10 Controller Working Positions, together with a connection to another ATC system (JANE).

Following the successful technical exercise the customer formally agreed that the 12 identified items for demonstration had been witnessed in a run lasting over an hour, with more than 60 aircraft progressed through the system. The technical exercise had demonstrated the capability of the platform in terms of configuration, flexibility and scalability.

The following table lists the items for demonstration that were witnessed:

Item for demonstration
Control the lifecycle of an exercise: create/initialise/freeze/destroy
At least 2 hours duration of an exercise
200 airspace fixes in the playing area
Airports configured in exercise
At least 10 CWPs (5 sectors for Planner, Executive and Feeder roles)
Minimum information available on flights via the CWP: Callsign, Mode A, Mode C, speed, heading, destination Dynamic flight legs (trajectory)
Pseudo-pilots in R/T contact with controllers
Progress flights through the system: Takeoff-SID-Climb to CFLK - Cruise – Start descent – STAR – Land
Control flights: Assume responsibility Give heading Change cleared flight level Transfer to next sector/ATC Centre
Exchange information with other systems (JANE)
Recording of exercise data
Interpret recorded exercise data

The following deliverables were produced by this Work Package:

- D5.1 Technical Exercise Strategy Plan
- D5.3 Technical Exercise Report

D5.2 User Guide was included as part of D4.2

5. CRITICAL ISSUES AND LESSONS LEARNT

5.1 Critical issues

Major difficulties were experienced during the first half of the project. These arose from diverging views on the objectives of the project (i.e. the degree of validation which could be performed with the first instance) and diverging partner interests (leadership; origin of the components and of the APIs). But, also from the difficulty in defining a methodology which could take into account simultaneously the definition of a generic model (which was instance independent) and the development of a first instance of the platform, from the requirements to the test descriptions.

Due to these difficulties and the lack of progress, the architecture definition took much more time and effort than planned. A technical audit of the project was carried out which aimed to check the correctness of the initial results. This meant that component adaptation was delayed by 8 months and it was decided not to transfer effort between work packages to balance the overspent effort in WP2.

As a result of the audit, the partners agreed to reinforce the management process by setting up a Technical Management Cell (to co-ordinate an agreed way-ahead) and a Design Team (to raise technical issues and possible solutions, especially related to architecture design). This enabled the consortium to give a high priority to the API delivery and to propose a staggered plan that identified successive priorities in the building of the platform.

The second half of the project, following the audit, was much more satisfactory. Most partners were fully committed, worked well togetherand the new organisation proved its efficiency. The outputs concerning the architecture of the platform and the design of the first instance were of good quality but their production was slower than planned, as was the delivery of the infrastructure tools. Hence, it was decided to request a delay to the end of the project by 6 months.

The adaptation phase and, above all, the integration phase were late starting as partners were occupied by other project activities.In addition, the overspent effort during the architecture definition phase had a consequence for both the adaptation and integration activities. This had the effect of reducing the scope of adaptation for some partners and also reducing the level of commitment to the integration phase for others. The definition and description of the integration tests were difficult. The integration met unexpected difficulties such as:

- *some significant delays in component delivery,*
- *reluctance by some partners to spent appropriate time at the integration site,*
- *differing levels of local testing prior to delivery to the integration site,*
- *too long spent correcting identified defects following allocation to a partner,*
- *non-attendance of some partners at several consecutive technical meetings making the whole process unmanageable.*

The MDR (Modification or Defect Report) process was successful, the management was robust and efficient, but the time to close an identified MDR was often too long.

However, due to shortage of time and low participation by and lack of resources for some partners it was not possible to adapt and integrate all selected components (13 out of 20 were integrated) or perform all the planned tests. The difficulties in integration (often coming from the components themselves) lead to the technical exercise being performed at the last possible moment in the project.

The following critical issues arose during the project:

- Strategic

  - lack of adherence to the EC objectives
  - external political issues
  - diverging motivation in the participation of the various partners
- Economic and contractual
  - lack of funding
  - lack of flexibility in the updating of the objectives
  - lack of flexibility in the definition of partners contribution
- Organisational
  - number and location of the participants
  - poor involvement by some participants
  - poor involvement of the EC, who will not directly use the results
  - difficulties in having the right people involved at the right time
- Technical
  - the scope of the objectives was too broad
  - technical bottlenecks
  - difficulties in the estimation of effort

Although AVENUE was a collaborative project which 13 partners agreed to join, the individual interests and objectives of those partners and the EC were different:

- Background : diverging views of :
  - how to improve the ATC systems (standardisation, integrated validations)
  - the role of each partner (EC, Industry, EEC, R&D...) and the collaboration between them
- Different objectives, different motivation, different interests concerning the results and their use

  (e.g. requirement for early validation experiments using the platform; reuse of the adapted components and of the first instance after the end of the project)

It has been difficult to define, understand and prioritise the objectives of the project, both for the consortium and the EC.

The objectives were too ambitious considering the budget and schedule, but it was not possible to reduce them.

The complexity of the system architecture definition was underestimated.

It was optimistic to think that early validation experiments could be carried out using this platform with the selected components.

The management structure was not sufficiently efficient at the beginning of the project.

5.2 Lessons learnt

It must be understood that the need to involve all the key players and to reach a consensus is not compatible with short term efficiency.

It is important to have a common view of the objectives and desired results of the project before the beginning of the contract.

It is important that each partner is rewarded for his participation by concrete results which are really useful to him (and not only for the money).

It is difficult to manage, have a good overview and to be fully motivated in a project that is 50% funded by the participants.

It is difficult to manage and have a fully committed team in a three year project of this size and type.

It is important to allow sufficient flexibility:

- in the modification of the objectives during the project
- in each partners participation (including component delivery and effort levels)
- in the distribution of effort to the tasks (Work Packages).

It is important that the conditions of the contract reflect the rules and structures that will be applied during the project (i.e. management of the WPs) and also provide the required flexibility.

It is important to define objectives which are achievable with the available resources (as it impossible to maintain motivation if effort is overspent).

It is important to find a consistent structure for the management and co-ordination.

Technicians with a well defined mission work well when they are not disturbed by “political issues”. They must however by aware of the overall objectives to avoid making technical decisions which contradict the direction of the project.

The integration process remains a difficult activity requiring:

- adequate effort, scheduling, availability and commitment
- an industry-based methodology
- fully tested components
- a large amount of energy
- configuration and supervision tools
- a robust and efficient HMI integrated as soon as possible (if this is appropriate to the application)

There are differences in the working methods of the various organisations and it is difficult to arrive at a “pan–European” way of working.

6. PARALLEL ACTIVITIES AND REUSE OF THE RESULTS

6.1 MOU

One of the most important objectives of the AVENUE project was to develop and to demonstrate an open ATC platform suitable for the validation of advanced operational concepts. During the negotiation phase, some partners suggested that, to meet such an objective, it was important to have more than one implementation of some key components (e.g. FDP). This was not feasible within the frame of the AVENUE project due to budget constraints. Recognising that it was the best way to demonstrate this openness, the EC proposed to set up the mechanism used so far, through a satellite contract or Memorandum of Understanding (MOU). When proposed to the AVENUE partners, only two of them decided to prepare MOUs: Airsys ATM and SOFREAVIA/DNA. EEC was involved in these MOUs for the integration of the components (with a lower priority than for the selected AVENUE components).

6.1.1 MOU SOFREAVIA

A Memorandum of Understanding was agreed in 1998 between the European Commission, Eurocontrol and SOFREAVIA/DNA. The objective of this MOU was to demonstrate the flexibility and the interoperability (i.e. to demonstrate that the architecture was not component driven) of the AVENUE Architecture and APIs.

This MoU initially encompassed the adaptation to the AVENUE architecture of:

- The "DAARWIN" Flight Data Processing and Distribution (FDPD) system (flight plan management, constraint management, trajectory prediction, sectorization and co-ordination)
- The ODS France Controller Working Position (CWP)

DAARWIN is the DNA/CENA research ATC simulator used for real-time validation experimentation. It is based on a client/server architecture using PHARE/CMS APIs. ODS France is the French operational CWP.

The adaptation of DAARWIN comprised the following steps :

- Adaptation of the whole DAARWIN simulator to the AVENUE APIs.
- Integration into an AVENUE container to replace the SACTA FDPD component.
- Removal of the embedded trajectory prediction function from DAARWIN, and integration with the CINCAT/TP component (with the capability to dynamically switch from the CINCAT/TP to the DAARWIN/TP).

The adapted ODS France CWP was in the end not integrated into the AVENUE platform at Brétigny due to the need for specific hardware and software.

DAARWIN was first adapted and pre-integrated at CENA Toulouse, using a light AVENUE platform provided by Eurocontrol to each partner of the project, and then integrated onto the AVENUE platform at EEC.

A demonstration of the MoU was performed during the AVENUE Final Presentation on the 22nd of March 2001 at Eurocontrol. This demonstration consisted of exchanging the SACTA FDPD component with the DAARWIN one, and running the operational exercise.

This MoU highlighted:

- The maturity of the APIs developed in the AVENUE project, but also the need for a more Business oriented Data Model, and for a common interpretation of data semantics.
- The advantages of the CORBA3 Component Model for the flexibility and the understanding of the platform architecture
- The importance of Configuration Management, to successfully exchange components between two separates sites (EEC at Brétigny, CENA at Toulouse).

6.1.2 MOU AIRSYS ATM SA

An MoU was prepared by Airsys ATM in 1998 aiming at porting the FDP E2000 component onto the AVENUE architecture. This was signed by EUROCONTROL and AIRSYS ATM, then sent for signature to the European Commission. Due to various reasons related to internal organisational changes of EC and loss of the original documents, the MOU was an outstanding problem during the course of the project, but was finally signed by the EC at the end of the project, March 2001. Two main parts were covered by the Airsys ATM MoU:

- The E2000 FDP component would be adapted by Airsys ATM to the AVENUE architecture,
- The E2000 FDP component would be integrated by EEC onto the AVENUE platform at the EEC premises in Brétigny.

From the above definition, the Airsys ATM response to the MOU has been the Prototyping Platform ADEPT.

What were the pre-requisites of ADEPT:

1. Airsys ATM operational FDP, Eurocat 2000,
2. AVENUE Logical Model to modularise the Airsys ATM system into AVENUE modules,
3. AVENUE APIs to interface modules together,
4. AVENUE architecture: integration of multi-origin components onto a CORBA- based platform.
5. linkage the expected result with other projects: re-use of PATIO architecture outcomes.

Therefore, a progressive approach was started in 1998, based on:

- use of recognised ATM models (OMG, AVENUE APIs)
- ADEPT design based on European modularity concepts (PATIO, AVENUE, …)
- Based on COTS
- Based on new decade technologies (CORBA, Java, ...)
- Use of fine grain architecture concept
- Shall be independent of the target machines
- Provision of an open, flexible and easily maintainable system
- Compliance with AVENUE APIs and Data Dictionary
- Allow transition between existing system and future one
- Use of multi-languages software

As a result, ADEPT is today providing a complete R&D platform for development, testing and evaluation. It provides a representative set of Centre functions:

- TP, Correlation, ATC Constraints, …
- from AATM existing Components: Sectorisation, IFPS, Route Extraction, …

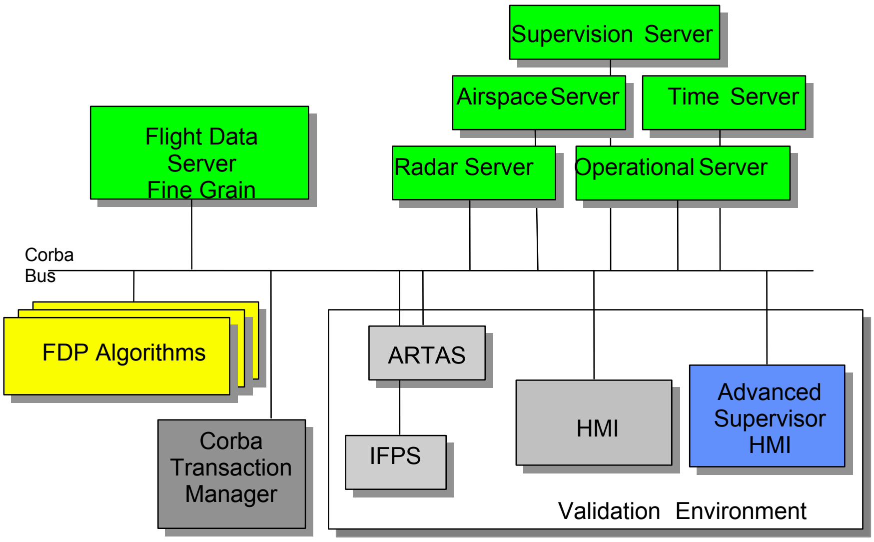

Figure 6-1: ADEPT Platform

In conclusion, ADEPT has been a tangible proof that an operational system, in this case Eurocat 2000, can be implemented on an AVENUE architecture and that the AVENUE APIs have a good level of maturity to deal with such system.

Nevertheless, performance remains weak and does not bring sufficient proof to convince Airsys ATM to fully adopt such architecture in our coming system. Important work is still to be done, mainly:

- enhancement of the current architecture to support operational system constraints (e.g. redundancy, safety, …),
- enhancement of the API to support the whole ATC domain and with regard to the future functionality (AMAN, DMAN, SMGCS, …)

Part of this work can be performed through the Gate to Gate project (2001-2005), as a continuation of the AVENUE project, and for Airsys ATM through future developments on the ADEPT platform.

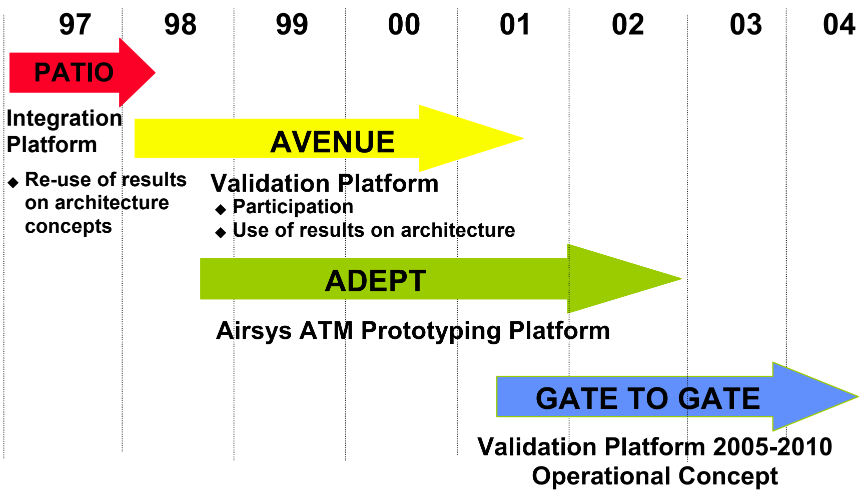

Figure 6-2: Links with other R&D projects

6.2 Future projects

6.2.1 GTG

One of the tasks of the 5th FP (called "operational platform for a European ATM system in the medium time frame (2005-2010)") is dedicated to initialising the Operational Platform for the ground segment based on previous work., This will be complementary to the airborne ATM technology platform developed in the Aeronautics Key action.

The objective of the GTG project is to validate the next generation European Gate to Gate ATM system through large scale real-time and fast-time simulations with particular reference to safety, capacity and cost for the time period 2005-2010 according to the TORCH concept :

- The demonstration of the full gate-to-gate ATM system will be done via a staged integration and trial process: planning, consolidation, preparation and validation of the ATM En-route segment then En-route/TMA then En-route/TMA/A-SMGCS. The objective, as said before, is to gain confidence in that the proposed solutions could cope with the forecast traffic growth in terms of capacity, efficiency, safety and cost.
- The work is/will be based on the defined ATM concept, developed in the TORCH project and stemming from the EATCHIP EATMS Operational Concept Document (OCD) and the work done within the ATM 2000+ Strategy activity. The output from TORCH is expected to produce a concept and scenarios with identified areas for investigation, quantified and measurable objectives for validation.

Continuing the work done in AVENUE, the most promising ATM and CNS elements previously developed in European, national or other (industry, research) organisations will be put together and validated, together with new operational procedures and methods, in order to make recommendations for standardisation and implementation. In particular, the processes to define mutually agreed "de-facto" system standards (architecture, middleware, Application Programming Interfaces) will be continued.

An added value to the member states and industry is the provision of a focal European validation service where the stakeholders for a low cost are able to test their candidate ATM and/or CNS components and validate their suitability.

The architecture will be based on the architecture of AVENUE (Logical Model, Data dictionary, API) and at least partly on the infrastructure developed around CORBA3.

A Configuration management board for the API will be established and will assure the continuity between AVENUE and GTG.

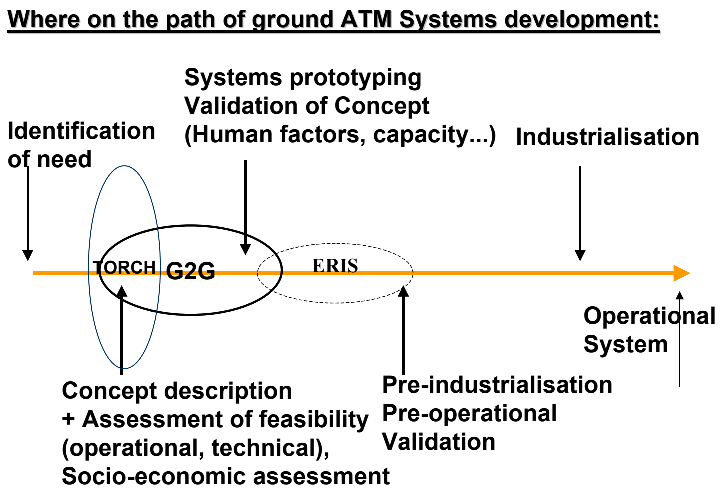

Figure 6-3: GTG and future projects

6.2.2 ERIS

AVENUE will be a solid input for the ERIS Programme of EUROCONTROL.

ERIS (EATMP Reference Industry based Simulation and trials platform) is a EUROCONTROL EATMP Programme and a EUROCONTROL Experimental Business area.

The objectives are:

- To provide an industry based reference validation platform and integration facility to EATMP and EC validation projects.
- To support ATM study projects confirming ECIP objectives.
- To participate in the EC 5th Framework Gate2Gate 2005 consortium.
- To provide an open, transparent and neutral environment conducive to bringing competing industries together.

Under the ERIS programme strategy the EEC simulation capability, ESCAPE (Eurocontrol Simulation Capability And Platform for Experimentation) is to be aligned with industry based architectural standards and API's realised during the EC 4th Framework AVENUE project (ATM Validation ENvironment for Use towards EATMS).

This strategy is aimed at enabling an industry-based approach to simulation and trials development through common agreed technical standards. Such an approach is expected to enable industry to participate earlier in the validation life cycle of advanced ATM concepts thus reducing the path to implementation. Additionally this will help the EEC reduce its development effort by contracting out development to industry partners subscribing to the same architecture standards and APIs.

The evolution of technology and the position of ERIS and its stakeholders require the EEC simulation and trials capability to be upgraded with modern systems management, design and documentation techniques and tools. The ACE (AVENUE Compliant ESCAPE) project will provide for this as well as the introduction of the first industry based components.

Specific Objectives:

1. ACE shall provide AVENUE compliance by:
   - Adopting the AVENUE Data Dictionary (Data APIs which represent a common model for data).
   - Adopting AVENUE APIs (Service APIs) which represents the logical decomposition of ATM functionality (along with the description of corresponding interfaces ATM functionality should provide).

2. ACE shall improve the integration of “third party components” and de-couple ATC-domain applications from pure communication matters.
3. ACE shall enhance the maintenance of the ESCAPE platform both at software production and software documentation levels.
4. ACE shall improve the usability of the platform at the level of the configuration, and technical and operational supervision.

The ACE project shall provide the ERIS programme with the next major version of ATC real-time simulation platform.

This major upgrade particularly addresses the areas of:

- “Standardisation” to improve the flexibility and connectivity of the platform,
- “Maintainability” to improve the maintenance process and quality of platform software and documentation.

7. CONCLUSIONS

The AVENUE project can be considered as a success:

- An architecture (API + data dictionary) has been defined with a wide consensus and will be put into the public domain as a *de-facto* standard for validation platforms,
- A methodology has been defined to build platform instances from requirements and definition of services to test and demonstration, giving a clear boundary between the generic part and the instance dependent part,
- It has been proved that it was possible to integrate heterogeneous components to this architecture (openness), to replace a component by another one (TP, MASS and in a parallel activity to the project, FDP with Sofréavia MOU) (demonstrating flexibility and robustness of the interfaces).
- The integration of the components and the technical exercise (with 10 CWPs + 5 pseudo-pilots, 60 flight scenario, 5 sectors simulated by the AVENUE platform; 3 adjacent sectors simulated by the remote JANE platform) have shown the potential of the architecture and infrastructure for an almost full ground-part of an ATM validation platform along with limited D/L capabilities and a first connection of two different ATM platforms for distributed simulations, in a distributed environment of 30 computers (the AVENUE platform itself).
- If the robustness and the performance of the platform have not been completely demonstrated, the integration and the technical exercise did not identify problems coming from the architecture or the infrastructure.

The first instance of the platform does not allow early validation experiments, which was one of the objectives of the EC.

We think that the API and Data Dictionary and the infrastructure based on CORBA technology could be the foundation on which large-scale real-time validation activities in the Fifth Frameworkwill be built. Some partners have already decided to use the results of this project for their validation platforms (EEC programme ERIS, some ATS providers, research establishments and industry).

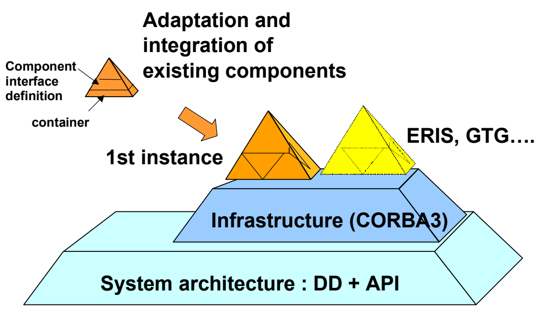

Figure 7-1 : A basis for future platforms

Some of the lessons learnt, which are described in this paper, relating to the management of such projects could be applied to future projects of this type.

Note that even if the APIs which have been defined and demonstrated can be considered as *de facto* standards for validation platforms, another significant step remains to prove their correctness for operational systems. This also applies to the correctness of the technical infrastructure based on CORBA. A new functional/systems development strategy has to be defined to deliver operational ATM systems, without having the gap between “pre-operational“ systems for validation purposes and the actual operational systems.

All AVENUE documentation is available on the web site: http://www.eurocontrol.fr/projects/avenue

8. APPENDIX A: RESUME OF THE DELIVERABLES

These documents are available on the web site www.eurocontrol.fr/projects/avenue.

8.1 D1.1 Consolidated Requirements Document

The document is divided into four main chapters:

- Scope: which includes the general approach to the definition of requirements, as well as the types of requirements. The structure of the requirements is presented.
- Methodology: consisting of a description of the methodology used for deriving and grouping the requirements, including a description of the platform mission, the platform users, the platform environment and platform boundaries.
- Analysis of the requirements: which includes some statistics from the requirements defined, as well as some guidelines for using the database developed by Isdefe to follow the traceability of the requirements.
- Conclusions: a summary of the work done.

In addition, Appendix A to the document presents the ATM System Life Cycle being used for the definition of the requirements of the platform.

Appendix B to the document presents a list of the expectations identified in the project.

Appendix C to the document presents a list of the High Level Requirements identified in the project.

Appendix D to the document presents a list of the Low Level Requirements identified in the project.

Appendix E to the document presents a list of the Platform Performance Requirements identified in the project.

Appendix F to the document presents a list of the Platform System Requirements identified in the project.

Appendix G to the document presents a description of the Data Base developed to follow the traceability of the requirements.

8.2 D2.1 SSS System/Subsystem Specification

The SSS is the first volume in the AVENUE architecture document hierarchy.

It specifies the AVENUE System, including a set of functions, with high level requirements derived from the Consolidated Requirements document (D1.1 – see section 8.1) produced in Work Package 1.

Upward and downward traceability is ensured for each requirement that identifies:

- The link with Low Level Requirements in D1.1.
- When the requirements description has reached a stable state ready for approval.
- The status of the requirement - "not approved", "approved" or "validated".
- Whether the requirement is met in the first instance of AVENUE.

8.3 D2.2 SSDD System/subsystem design Description

As shown in the Life cycle representation in section 4.2, the system design activities have covered initially the generic aspect of the AVENUE architecture and then the specific instantiation of this architecture, the

AVENUE first instance. Therefore, each aspect of the design leads to a specific part of the SSDD document (i.e. the generic part and the physical part).

SSDD part 1 covers the generic architecture with:

- System Wide Design Decisions that deals with:
  - The methodology applied to the challenges faced by the AVENUE project.
  - The design choices for the software architecture: technical infrastructure overview, design centres definition (i.e. component/container model, event model, data model, Interconnection model), and orthogonal services definition. Note that hardware architecture is not considered to be a matter of the generic architecture but is instance specific.
- System logical design. Also called the logical model, it functionally defines the ATC ground system in terms of modules (i.e. logical entity that covers one or more specific ATC functions) and the interactions between them (i.e. data flows). It is independent of any implementation.

SSDD part 2 covers the first instance of the AVENUE platform with:

- The physical architecture of the platform, in terms of identified physical components and the expected hardware architecture,
- A description of each component (i.e. role and functional aspects), the relationships with other components, and the general strategy for the integration in the technical infrastructure,
- the Model of Execution describing the dynamic behaviour of the platform. Note that the static aspects of the Model of Execution are depicted for each component in the WP3 deliverable (D3.x).

Traceability of the requirements to the SSS document is also performed.

8.4 D2.3 IRS Interface Requirements Specification

Deliverable D2.3 is composed of two documents: the 'IRS' (Interface Requirements Specification) itself and the 'API Style Guide'.

IRS belongs to the generic aspect of the architecture. It describes the APIs and Data Dictionary, which are instance independent. The AVENUE IRS is mainly a compilation of the IDL files (describing the APIs and Data Dictionary - D2.5 – see section 8.6) presented in a more readable form with HTML links and pertinent information exchanged during the definition of DD and APIs, i.e the Memos or Technical Notes exchanged during the [illegible]2.7 task. High level (UML) diagrams have been prepared to provide an overview of some parts of the Data[illegible]tionary.

The 'API Style Guide' document was written before the API definition to support the production of the interface in IDL language. This document provides guidance concerning the use of CORBA IDL (relative to both CORBA2.2 and CORBA3.0).

8.5 D2.4 SUM of common tools

Deliverable D2.4 is a collection of documents produced in the context of [illegible]k 2.8 of Work Package 2 (architecture definition) or reference documents for the infrastructure (OAS[illegible]PLUG). These documents constitute a SUM (Software User Manual) for the infrastructure of the AVENUE first instance. The PLUG SUM is delivered under an AIRSYS ATM SA licence.

[illegible]01T11 is the entry point of the deliverable. The other documents are:

- Design Centre Definition. It outlines the major design centres that form the basis of the AVENUE technical infrastructure.
- Component Adapter's Guides for C++ and Ada83. They provide a complete guide to developing CORBA components for the AVENUE first instance platform, built upon the EEC's OASIS middleware product.

- AVENUE Infrastructure Installation Guide. It provides a complete guide for the installation of the AVENUE Infrastructure product.
- Data Model User Guide. It covers design principles for the Data Model, IDL interface documentation and product documentation (i.e. using the data model generator)
- Infrastructure Platform User Guide. It is concerned with the administration of the Infrastructure platform.

8.6 D2.5 IDL packages

Deliverable D2.5 constitutes the collection of IDL files for AVENUE Data Dictionary and APIs produced in the context of Task 2.7 of Work Package 2 (architecture definition). They correspond to the last version of the Data Dictionary and API IDL files developed in the context of AVENUE project.

Note that the deliverable D2.4 (AVENUE IRS) uses the types and services defined within these IDL files.

8.7 D2.6 Software packages

The Software Packages deliverable is a collection of software resulting from the infrastructure implementation, as follows:

- OASIS middleware (delivered under EEC licence)
- PLUG runtime (delivered under AIRSYS ATM SA licence)
- CID (Component Interface Definition)

Component Interface Definition (CID) is written in IDL3 in conformance with the Corba Component Model approach. The CID is used to generate the container of the component as it gives a standard definition of all provided and used interfaces of a particular physical component. The CID is the layer above the APIs. While APIs cover logical entities and have been defined independently of any implementation the CID deals with a specific implementation and concerns a physical entity.

8.8 D3.1 Component Adaptation Description Documents

These documents are intended to be part of the documentation package available from the project to support further adaptation activities, for different components, by other partners or for different instances of the architecture. As such, the documents do not contain an internal design description of the component but a general overview, the documents also contain a description of the adaptation process performed and the CID defined, and the test procedures and results obtained during the local testing of the component.

Each document is divided in 5 main chapters, the first being the introduction:

- Chapter 2 contains the identification and adaptation strategy of the component
- Chapter 3 describes the connectivity of the component with the rest of the platform
- Chapter 4 summarises the adaptation process performed
- Chapter 5 provides a summary of the local tests performed and local environment prior to the delivery for integration

8.9 D4.1 Test & Integration Master Plan

The Test and Integration Master Plan (TIMP) defines the overall strategy for the delivery, integration, test and evaluation of the components into the AVENUE platform. The primary purpose of this effort is to demonstrate that:

- the architecture is feasible, and
- the platform "works" and can be used for validation experiments.

The TIMP also defines the methodology used to assess to what extend the requirements are met. In line with the stepwise approach selected for the adaptation and integration within AVENUE, the TIMP has been produced in two issues :

- issue one, "TIMP Step 1", covers the integration of the "core ground" platform and is comprised of components from Step 1A, Step 1B and Step 1C.
- issue two, "TIMP Step 2", covers the integration of the "enhanced air part" and data link elements of the platform and is comprised of components from Step 2A and Step 2B.

The document is divided in 4 main chapters:

- Introduction
- Chapter 2 refers to the strategy and methodology to be used for integration
- Chapter 3 describes the test environment and the successive steps and their sub-steps
- Chapter 4 provides a description of all the integration tests (not the details of the test which are referenced in an Annex)

8.10 D4.2 Configuration Management Document

The purpose of this document is to describe the AVENUE Software Configuration Management (Control of the configuration, modification process, archiving and deliveries). It addresses [illegible]e areas:

- section 3 of the document describes the Software Configuration Management (SCM) procedures and activities performed within the AVENUE project. This includes procedures for reporting and registering problems, procedures for deciding on corrective action, and the identification, update and release of Configuration Items (CIs) in a controlled manner. The process was based on the Continuus ® tool.
- section 4 of the document describes the Data Preparation procedures and activities to be performed within the AVENUE project..
- The purpose of section 5 of the document is to describe the AVENUE Change Management system, and to identify the responsible people and their roles. It describes the process around Modification and Defect Reports (MDRs), the different MDR states, the processing times, and the tool used (Remedy ®)

8.11 D4.3 Platform Technical Documentation

This document, the Platform Site and User Guide, is a guide which describes the EEC site (location, access, etc.) and also the AVENUE platform used by the integration team for the management of the first instance of the platform (identification, installation of software, data preparation). The document is divided in 7 main chapters, the first being the introduction :

- Chapter 2 refers to the site access and location.
- Chapter 3 refers to the names and roles, contact list and the process for platform reservation.
- Chapter 4 provides the platform description.
- Chapter 5 describes identification of the AVENUE software and data preparation
- Chapter 6 explains the installation and the use of the platform.
- Chapter 7, the annex, describes the known problems and the equipment,

8.12 D5.1 Technical Exercise Strategy Plan

The purpose of the Technical Exercise (TE) in WP5 was to demonstrate the capability of the developed facility and its suitability for large-scale real-time validation activities in the Fifth Framework. The Technical Exercise Strategy Plan (TESP) has two purposes:

a) To describe the objectives of the TE and the definition of the exercise itself, together with the planned stages needed to achieve the exercise.

b) To act as a management plan for WP5, since it defines all the planned steps.

The report discusses and defines 8 numbered objectives for the TE and cross-references these to a list of project success criteria.

A detailed definition of the TE is given, which discusses the audience for the TE and their expectations. It builds on previous work in WP1.5 of AVENUE to define the constituents of the exercises. The operational scenario and the traffic sample for the TE are also discussed. Logistics for the exercise are examined in terms of location, dates, schedule and personnel.

The activities within WP5 are detailed, covering 6 sub-tasks. This section acts as the management plan for WP5.

Following presentation of the proposed approach for the TE, the customer stated his interpretation of the objectives of the exercise and this resulted in a change of emphasis. This led to the development of 15 “items for demonstration” that taken together would form the basis for the TE. The revised approach is included as a separate chapter in the report.

8.13 D5.2 User guide

Included in D4.3.

8.14 D5.3 Technical Exercise Report

The purpose of this report is to describe the results of the technical exercise in terms of its organisation and conduct, as well as an explanation of the results given the objectives set for it.

The 8 numbered objectives of the Technical Exercise (TE) and the 15 items for demonstration developed in the Technical Exercise Strategy Plan are listed. The organisation and conduct of the TE are described, covering the 16 components within the platform configuration, the exercise scenario and summary of the capabilities of the controller working positions.

The technical exercise was performed at EEC, Brétigny on Wednesday 21st March 2001. The witnesses were Mr. C North of the EC and Mr. H Wagemans of EUROCONTROL HQ, acting as technical advisor to the EC. In summary, the exercise was conducted as follows:

- The platform was created and initialised using the technical supervision workstation.
- During the warm-up phase (i.e. whilst first aircraft enter the system), the CWP was demonstrated to show the track data blocks for each flight, together with the use of colour to indicate the aircraft state. Interaction with the system was shown by pointing at the fields of the track data block.
- One particular aircraft was followed through its lifecycle, from its creation in a feed sector, transfer to the next sector, controller orders to resolve a potential conflict with another aircraft and transfer to the next ATC centre.
- The use of datalink (CPDLC) was demonstrated at one sector position, in order to pass controller orders to the aircraft (i.e. pseudo-pilot position) without using the R/T.
- After approximately one hour, 60 aircraft had passed through the system and it was agreed that the exercise could be frozen and then destroyed.

- A formatted dump derived from a recording of a previous run was examined.

At the debrief session, the customer confirmed that 12 items had been demonstrated and that he was satisfied with the Technical Exercise. Formally, this constituted acceptance of the TE.

The conclusions of the Technical exercise are as follows:

- The technical exercise has demonstrated successfully the capability of the first instance platform of AVENUE, based on 12 items for demonstration and in terms of the following:
  - Configuration – definition of architecture, data dictionary, APIs, DMoE
  - Flexibility – components adapted to architecture
  - Scaleability – 10 controller working positions
- The first instance platform comprises relatively limited ATM functionality. This is a consequence of the “bottom up” approach starting from the given ATM components.
- The CWP was the most critical component because it affects both how the Controller can interact with the system. However, it was also the most difficult to adapt because it contains assumptions about the ATM system and the technical exercise did not have a starting ATM concept.
  -
- The technical exercise was a formal success as a demonstration of capability, which was its objective. Although the objective of the AVENEUE project is to enable validation of ATM concepts in the Fifth Framework, the objective of the TE was specifically not intended to undertake validation and, in particular, validation of the following:
  - An ATM concept – because no concept was specified as part of the project;
  - The AVENUE architecture – because this can only be validated truly through subsequent instances of an AVENUE platform, when it can be shown that components can continue to be adapted to new and different ATM concepts;
  - The first instance platform – because it is now clear that this will not be used further for any validation activities.
- The TE has shown the capability of the developed facility. This is one aspect of what the AVENUE project has shown overall and it supports the view that the AVENEUE architecture can be applied as the basis for large-scale validation activities in the Fifth Framework.