I2FDP

FDP Institutional Issues Study

Final Report

Contract n° B2001/B2-704B/S12.322054

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DOCUMENT REVIEW

Reference: Final_report_23.doc		N° Version: included in the name of the file
Drafted by:	D. Hollinger, P. Naves, E. Von den Steinen, M. Delarche, J. Moyaux	Date:
Verified by:	J. Moyaux	Date: 11/07/02
Authorised by:	J. Moyaux	Date: 11/07/02

DOCUMENT LOG

Version	Date	Description of evolution	Modifications
10	29/04/02	1st Draft sent to the client	
20	06/06/02	2 version sent to the client	After comments from the EC on the 1st version
21	07/06/02	Editorial modifications	
22	20/06/02	Editorial modifications Addition second recommendation Addition fig (new) 4.1, 7.1, 7.3, 7.4; modification 7.5 Addition general process definition (standardisation)	§ 1.4.4, 1.5.1, 5.1.2, 7.3.5 § 5.2.1 §7.6.1
23	11/07/02	Explanation on voluntary standards	§4.4.3.1

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EXECUTIVE SUMMARY

I. INTRODUCTION AND GENERAL PURPOSES OF THE STUDY

In this Study the Sofréavia team was asked to identify and analyse institutional issues affecting the development of flight data processing (FDP) systems and services at the European level. FDP, while a complex technical area in its own right, and therefore meriting specialised analysis and approach, also stands in the centre of ATM service development. A key basic finding of this Study is that both legally and operationally FDP has been regarded (and largely continues to be regarded) as an element of core ATC service. Whether viewing it as an element of core services still leads logically to embedding it in the discrete designs of diverse local systems must, however, be analysed as an entirely distinct question.

Today's national and local FDP systems do not achieve interoperability. Even conservative stakeholders agree that without significant standardisation, they will not meet the demands of European aviation. In close co-operation with Eurocontrol, the European Commission has called for an investigation into European-wide organisational and funding mechanisms and structures for the common and efficient specification of interoperable systems in the field of flight data processing, their development, and provision of services based upon them. Thus this Study has sought to develop recommendations that could be used to:

- identify a vision, routes of evolution towards, and final configurations of, future FDP (and later other ATM) systems (agreed on by a majority of stakeholders), including their definition, procurement, development and exploitation in the context of the economic regulation,
- mandate standardisation bodies with clear and well defined tasks for the production of ATM standards,
- push forward the legislative and funding initiatives on interoperability and standardisation in line with strategy derived from conclusions.

This Study has addressed questions and themes posed by the Commission's original Terms of Reference presented in the following way:

- in Chapter 1, we introduce the Study and describe the methodology pursued;
- in Chapters 2-4, we attempt to establish systematically a technical, organisational and legal/institutional context for the inquiry. This has resulted in a set of **basic findings** presented below;
- in Chapters 5-7, we analyse opportunities that can be exploited and risks that must be confronted with a view of reaching **recommendations,** in particular with respect to standardisation, designed to advance the interoperability of flight data processing and the efficiency of its service provision.

II. BASIC FINDINGS OF THE STUDY

II.1. Architectural Issues

Chapter 2 examines the feasibility of different options for future FDP architecture based on the initial definition of a target ATM/CNS logical architecture. This led to the comparison of alternatives including the issues of transition. We then asked a wide range of expert stakeholders to evaluate these options. Some key findings of this inquiry are:

- ATS providers stress the need for smooth transition to a more integrated or harmonised future system but cannot yet agree on its ideal shape.
- A large consensus does exist to base the design of the future ATSU's primarily on operational needs rather than national convenience. This entails a reduction of the current number of ATSU's, especially for the small FIR's and UIR's.
- However, rejection of a unique central system for FDP service provision is unanimous. The idea of an upper airspace controlled by a single ATSU with free flight possibilities has also not gained wide acceptance among ATSP's.

- A major fear about central systems is that in case of unavailability due to accident or in a period of crisis, a state may be prevented from meeting its sovereign responsibilities for airspace safety or national security.
- Even on a day-to-day basis, local specificity must be addressed by any new overall architecture.

From this enquiry, and taking into account the assessment of possible scenarios, a convergent architecture seems to emerge (see figure below). This architecture mixes the network of ATC FM's with an additional central node that makes the fusion of replicated parts of flight data, for the benefit of non-ATC and non-ATFM users. ATC FM's are located in ATSU's. This does not preclude the possibility of placing a cluster of ATSU's under the authority of one shared FM. In any case, there is a tendency towards a reduction in the number of ACC's.

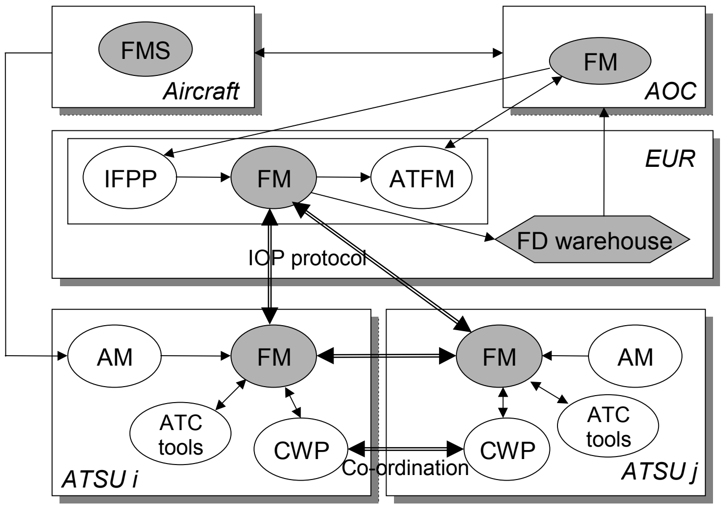


Figure ES.1: possible convergent scenario

II.2. Co-operative Organisation: Stakeholder Views and Relevant Precedents

Chapter 3 examines the context and outlook for institutional co-operation; first by presenting the views of representative stakeholders; and second by examining the experience of recent, relevant projects that have aimed to establish European levels of ATM performance. Our findings are presented below.

Stakeholder Views. Generally, questions were focussed in the following areas:

- which insufficiencies they detect in the existing regulation and organisation,
- what is their vision concerning the future organisation and regulation of the FDP system,
- what are the issues to be solved with such new organisation and how they can be solved.

A set of 23 stakeholders was consulted and 16 responses received. ATSPs responded massively (8 of 12) which suggests the topic is for them a matter of great interest and concern. The key findings of the stakeholder inquiry are:

- nearly unanimous support for modular specification,
- nearly unanimous support for shared procurements made on a voluntary basis,
- unanimous support for enhanced standardisation,
- solid support for EC-led regulation,
- significant resistance to specialised FDP service provision.

Most of the ATSPs agree that there will be more co-operation needed at regional level in planning, procurement, and possibly operation. They see here a role for the European institutions to foster the process. There is a debate about the means to achieve this co-operation:

- Some respondents are convinced that a consensus can only be forced by a political decision at European level. They would see the EC playing a role in the definition and supervision of ATM activities.
- Others believe that trans-national co-operation can only work on a voluntary basis and between small groups of states, the role of the European Union in the latter scheme being to encourage, e.g. by proper funding mechanisms, withdrawal from national to more functional and regional paradigms. They are not convinced that a single co-operation at EU level would be more efficient than what exists today.

All the stakeholders would like the European Commission to push the setting up of interoperability standards. The highest priority is given to the interoperability between Flight Managers (ACC, CFMU, Airlines…); this level should be mandatory.

Standards to improve interoperability between components (most of the time inside an ACC) in an open architecture are thought important, but with a lower priority and could be made on a voluntary basis. The stakeholders agree that a certain level of performance has to be defined, but the standards should not be too detailed technically. EUROCAE is seen as a good vehicle for this activity.

The process by which conformity of products, or systems, to standards is checked could be very costly; these costs must be carefully balanced against the expected benefits. Co-ordination between domains, programmes and institutions is required to reduce/avoid duplication, contradiction, conflict, overlap, redundancy, etc. The respective roles of EC, Eurocontrol and states have to be clarified concerning regulation activities.

The ATM manufacturing and supplier Industry also seeks a better partnership with the EC and Eurocontrol in the area of R&D programmes as well as in rules for future procurements.

Cooperative Projects' Experience. Some projects in the ATM-CNS field, conducted in a European collaborative context, are assessed in terms of their success or failure. The projects considered are ARTAS, eFDP, AVENUE:

- ARTAS – which is now one of the most advanced surveillance systems - has shown the difficulties of reducing the number of systems and coming to a fully seamless operation. This objective clashes with the will of ATS providers to retain full control over their systems –- even if this is at higher cost for them. The development and maintenance of a single system, replicated as many times as necessary is cost efficient; it may also conflict somewhat with the policy to promote competition and competence sharing amongst industry suppliers.
- The eFDP programme illustrates some of the common pitfalls of collaborative programmes (diverging interests; antagonistic approaches, methods, organisation; lack of efficient and binding decision-making processes). It proves that the common development and procurement of FDP is not possible in Europe today, because the interests of the suppliers are too different. Harmonisation and co-ordination are too costly for the achieved results. However a certain level of requirements produced by eFDP is now accepted as a solid basis for common requirements.
- AVENUE – which has successfully defined and validated on a common platform a set of commonly accepted API's - also illustrates the difficulties to arrive at common results when individual objectives and interests in a project with 13 participants differ. The need to involve all the key players and to reach a consensus does not mesh with short-term efficiency and ambitious objectives. But the criticism against this type of project can be tempered, as the building of convergent objectives and interests is as important as tangible technical results.

II.3. Legal and Institutional Context

Chapter 4 reviews the legal framework and the mandates and roles of key institutions in the current and anticipated regulatory and institutional environment. Examined are: ICAO, Eurocontrol, ECAC, current and contemplated EU regulations (including the draft regulations to establish the Single Sky), and the role of more specialised bodies such as the PRC/PRU, Eurocae, the CFDSG, the CFMU and EAD.

Decisions to be taken in future FDP development and funding or investment must respect the European performance dimension. The new Single Sky regulations tackle this at two broad levels:

- the encouragement of **individual initiatives** on the part of individual providers to innovate across borders;
- the strengthening of **collective responsibility** to establish, maintain and enforce common technical standards.

Our findings are:

- the idea of partnership is central to both individual initiative and collective responsibility. Thus the expertise and institutional structure that has developed under ECAC and Eurocontrol will remain valuable, indeed essential, especially to the degree that its operations reflect partnership and full commitment to provide timely and cost-effective solutions, pursued where technically advantageous through joint action.
- the Single Sky Committee to be created by EU legislation is positioned both to stimulate innovation and safeguard traditional interests. It is simultaneously an implementation mechanism empowered to design rules to achieve performance standards called for in the new legislation and a body positioned to review ongoing developments and recommend adjustments and innovations. A carefully crafted partnership with Eurocontrol will be indispensable in establishing quality controls and in gaining acceptance for its decision-making.
- especially (but not only) with respect to FDP systems innovation, competent European institutions in partnership with Member States, providers and other stakeholders may conclude that further steps are needed beyond the first package of Single Sky regulations:
    - the issue of co-ordinated research and development specifically identified by Member States in the *ECAC 2000+ Strategy*;
    - information policy: further rules on flight data access may need to be adopted to address possible gaps in the current legislation;
    - modularity and the possible establishment of economic as well as technical design criteria;
    - clarifying and standardising ATM systems performance liability.

III. RECOMMENDATIONS OF THE STUDY

III.1. Improving processes for FDP development and procurement and extending such improvements to future CNS/ATM systems projects.

<u>**Chapter 5**</u> discusses the types of collaborations that should be encouraged throughout the system definition life-cycle in view of a more efficient implementation of FDP systems in Europe taking account of the sensitivities involved, the degree of stated readiness for co-operation and the legal latitude. Partnership perspectives in FDP related research, development, and procurement have been assessed in turn together with the regulatory and funding initiatives that the Commission could take in this respect. The discussion has been extended to collaborative CNS/ATM systems projects when applicable.

The European Commission promotes actively the improvement of European ATM in general, and FDP systems in particular. But improving the ATM performance can only be achieved through stronger partnership between all stakeholders. Our recommendations to foster this necessary collaboration are:

- to encourage pragmatism by promoting standardisation and interoperability between systems rather than enforcing integrated trans-national concepts.
- to look for an overall co-ordination/liaison of the various working groups involved in the ATM architecture definition, ATM architectures standardisation, and ATM systems interoperability (Eurocontrol, Eurocae, CFDSG) in order to ensure technical consistency and avoid overlap or duplication of work.
- to promote interoperability standards leading to reduced development costs and accelerated development life-cycles through EUROCAE WG59 and WG61, with appropriate funding when necessary.

- to endorse CFD initiatives keeping in mind the necessity to find short term solutions and to take into account the requirements of the future controller tools, but being concerned with cost efficiency and the practical needs of the users.
- to co-ordinate and optimise the regulatory area by giving the Eurocontrol Agency a structural role in the development of implementation rules and standards.
- to promote the culture of performance through the definition of objectives, implementation plans, benchmarking and transparency, not only for operations proficiency but also for cost-effective development, procurement and implementation of interoperable systems.
- to continue and promote the partnership with industry suppliers , e.g. the 6th Framework Programme, the development of mock ups, the validation of pre-operational systems, and to invite suppliers to become more pro-active in global strategy definition.
- to promote collaborative projects involving two or more ATS providers (and Industry suppliers) that stimulate rapid transition to interoperability and connection to other systems, for example by appropriate funding support. Consistency with other projects should be assured by the participation of these stakeholders in the standardisation groups.
- in the co-ordination of R&D activities to stress integration of Industry projects into the global context and to push for the definition of a central body for management and control, e.g. under the umbrella of the ACARE initiative.
- to push and support those R&D programmes where the validation of common architectures, Data/link and tools for the controllers are pursued in a collaborative way.

This involves real cultural changes in management practices. This is a long process where every small step should be encouraged. Bottom up initiatives can fit in with top down decisions.

III.2. Recommendations in the area of Service Provision

In **Chapter 6**, we have conducted a preliminary description and analysis of the new organisational and operational relationship that would be created between the ATS provider and a separate FDP service provider in a service unbundling approach, contrasting it with current public service co-operative agreements. A number of issues have been addressed: contract-based service schemes, operational dependability, national security constraints, flight data access control, liability, and several organisational scenarios and their respective features have been sketched out.

Our main conclusions address the areas of:

- Identification of the "unbundling" potential of FDP services

  Consideration should be given to distinguishing formally the FD Distribution service from the FD Elaboration service. This should include a clarification in European regulation of where these FDP services would sit in respect of either ancillary services or Core ATC services. FD distribution to non ATC clients could be considered as an ancillary service that could be developed in the short term.

- Liability issues

  The current complexity of the legal framework, especially the current patchwork of national law in Europe that is applicable to ATM liability, and also the potential multiplicity of claimants and defenders in any litigation makes the establishment of a common ANS liability framework desirable.

  Before such a long-term ideal can be achieved, extending the GNSS-defined concept of contractual liability chain would be extremely helpful to clarify the relationship amongst the different potential service providers.

- Protection of Air Transport Security

  It is a sound principle of security to limit the real-time distribution of flight data to those parties that can demonstrate (to some security regulator) an operational need for having access to the flight intents and trajectory forecasts concerning flying aircraft.

  To reinforce the security of flight data exchange, the security regulator(s) should mandate the inclusion of user authentication and data integrity and confidentiality protection mechanisms in FDP service provision.

- Economic regulation

  The distribution of operational flight data is already regulated by the ICAO principle of cost-relatedness (and also restricted by air transport security concerns.) We can see no advantage in regulating the commercialisation of post-operational flight data, provided the service providers respect existing legislation on data protection. However, all the stakeholders request from the European Commission clearer regulation concerning data access which safeguards and facilitates the timely access to operational flight data, free of charge, to all the ATM providers as well as other qualified interested parties, with restricted access rules applicable to third parties.

  The construction of an economic rationale in respect of FDP service provision would require a detailed breakdown of CRCO-declared costs at the level of each ATS element and per ACC. Some regulatory action mandating ATS providers to make that information available is a pre-condition to any serious further work in that field.

- New forms for the organisation of service provision

  Having considered four options for modified or new forms of FDP service provision, we tentatively conclude that the best compromise between credibility, liability coverage, cost-effectiveness and flexibility seems to be what we term the ATSP-industry joint venture (broadly modelled on EAD). However, it would be applicable only to the distribution of flight data (at least for the short term), and too little information on the economics of FDP service provision is available to develop a robust rationale for any specific solution.

III.3. Recommendations on Organising the FDP Standardisation Process

Chapter 7 gives the "Standardisation Roadmap"; it describes the overall structure of FDP-related standards in line with the functional architecture model defined at chapter 2, taking into account the concrete implications of such architecture for organisation and regulation. We have described:

- which standards have to be developed to support the possible FDP architectures and service provision scenarios, in line with the breakdown of FDP services proposed at chapter 6, and
- what are their fundamental requirements (introduction of security mechanisms; explicit introduction of the notion of Area of Responsibility/Interest; need to guarantee the long term convergence between inter-centre and intra-centre data exchange structures, etc.).

On the basis of this analysis we propose a roadmap consisting of 4 steps, addressing both inter-centre and intra-centre (component level) inter-operability and performance issues.

Step	This step consists of:
Step 1: Enhanced inter-centre data exchange standard	- establishing a common flight data representation standard, - defining services and the associated protocols for the secure distribution of flight data in an open environment. Different functional levels of service may be defined, from the simpler level (ICAO format) to the more sophisticated (detailed 4D trajectory prediction).
Step 2: Flight data distribution performance standard	- specifying performance levels at the service interface of a Flight Manager, relatively to the distribution of the data, - describing compliance tests associated with these levels.
Step 3: Intra-centre data exchange standard	- reusing and supplementing the common flight data representation standard defined at step 1, - adopting a common FDP Architecture Model, and define the internal interactions between the FDP modules, and between the FDP modules and their environment (SUR, EM, AM), - defining services and the associated protocols for secure interactions between the Flight Manager and other Flight Data Processing Entities in an open environment (CWP, AMAN, DMAN, MTCD, etc.).
Step 4: FDP interaction performance standard	- specifying performance levels at the data exchange interface for each of the FDPE identified, either lying within the perimeter of the Core FDP or interacting with it from outside, - specifying performance levels for the accuracy of the exchanged data, between FMs and between FM and any functional module, - describing compliance tests associated with these performance levels.

An institutional (co-operative) and regulatory scenario for structuring and implementing the Standardisation Roadmap has been outlined.

The starting point for this scenario is:

- For the standardisation function:
    - The existing ICAO FPL SARPS and EUROCONTROL OLDI standard (OLDI has also been published as a European Standard),
    - The results of the Operational Interoperability Task Force and of the Overall CNS/ATM Target Architecture Group from Eurocontrol,
    - The 4 standardisation steps described in the Standardisation Roadmap,
    - The existence of a EUROCAE Working Group dedicated to the inter-operability standardisation of inter-ACC FDP interfaces (WG 59),
    - The existence of a EUROCAE Working Group dedicated to the definition of an industrially viable and sustainable open ATC System architecture and its standard interfaces towards the other entities in the ATM/CNS context (e.g. Radar Systems, ATFM Units, Aircraft Operators, Airports Operators, etc.) (WG 61).
- For the regulatory function:
    - The draft Single Sky regulation on the provision of ANS service,
    - A soon-to-be-defined Memorandum of Understanding between the European Commission and EUROCONTROL,
    - The existence of an ENPRM process at the level of EUROCONTROL,
    - The existence of 2 bodies dedicated to regulation in EUROCONTROL, the SRC/SRU that is dedicated to Safety Regulation (its rules are published as ESARR) and the RU that is dedicated to non-safety regulatory activities.

The approach we recommend to solve co-ordination problems is:

- include in the future Memorandum of Understanding between the Commission and Eurocontrol provisions enabling the Commission to issue mandates to the Eurocontrol Agency for the preparation of implementation rules, complemented by standardisation mandates to be given to EUROCAE or other voluntary standardisation bodies;
- put the RU in charge of co-ordinating the production of inter-operability, performance and security regulations on behalf of the EC (including the verification of compatibility with existing ICAO rules and standards), keeping the SRC in charge of safety issues ;
- organise the work of the RU and SRU as a co-ordinated ENPRM process (the RU should validate first the inter-operability and performance aspects which are not currently covered by the SRC/SRU in their safety reviews, then, on that already partially consolidated basis, the SRC/SRU would address any safety issues arising in the preparation of inter-operability and/or performance rules).

With respect to **<u>Qualification and Certification</u>**, we recommend to:

- create a European-wide certificate for Core FDP systems based on the EUROCAE standards described in the roadmap,
- for legacy interoperability (i.e. with ICAO FPL and OLDI) rely on industry qualification and self-assessment,
- because of the cost of providing a complete testing environment for FDP, and unless the industry is willing to provide for it on a co-operative basis, consider establishing a common European facility for conducting conformance testing and deliver inter-operability and performance labels, without excluding the provision of such certification services by other entities
- when the standards and associated performance labels have been in application on a voluntary basis for some years, issue a regulation imposing the recognition of those labels and mandating their use in call for tenders for FDP system and service procurement.

1. INTRODUCTION

1.1. Purpose of the document

The purpose of this document is to describe the objectives and results of the FDP Institutional Study. The main results will be presented to the stakeholders during a workshop.

It takes into account the answers to a questionnaire that has been sent to the stakeholders.

1.2. Document structure

Following an executive summary, this introduction presents:

- the structure of the document and the study organisation,
- the main definitions relative to FDP,
- the general background to the Study,
- a statement of the FDP problem: identification of basic deficiencies,
- the rationale and goals of the study,
- the analytic approach, research methodology used in the Study.

Chapter 2 defines and examines FDP development options,

Chapter 3 “Organisational Issues of Co-operation ” describes and analyses stakeholder views and assesses certain projects that have been done in a European collaborative way,

Chapter 4 discusses the Institutional and legal context (policy and decision-making context and the established roles of institutional actors),

Chapter 5 provides recommendations for the development and procurement of FDP systems and considers the possible extension of these findings to other ATM systems,

Chapter 6 examines FDP service provision, data ownership and data access issues,

Chapter 7 considers questions of standardisation and certification and presents a Standardisation Roadmap.

Annex A lists sources and documentation.

Annex B contains the glossary.

Annex C attaches the questionnaire that was to the stakeholders.

Annex D provides background on technical architectures.

Annex E gives a flight data description.

Annex F addresses Flight Data consistency.

Annex G discusses standardisation and certification definition and relationship.

1.3. Study organisation

The findings of the Final Report of the High Level Group [D1][1] have been taken as the governing strategic policy guidance for this Study. In this context, we have addressed the specific work packages set forth by the Commission in the Terms of Reference for this Study and, under the project management of Joël Moyaux, assembled a team of experts to examine the following relevant areas:

- Feasibility of alternative FDP system architectures to address future needs [Dominique Hollinger]

[1] The principal sources, listed and coded in Annex A, are cited by code reference in the text.

- Capacity of organisational arrangements to identify and solve technical problems [Philippe Naves, Joël Moyaux]
- Potentials and problems of the current and evolving policy, institutional and legal environment [Erwin von den Steinen, Pablo Mendès de Leon]
- Data and information management issues and the structuring of future communications service provision [Michel Delarche]
- Optimisation of regulatory procedures for the modernisation of technical systems [Michel Delarche].

1.4. Definitions relative to FDP components

1.4.1. General

For a definition of what we term FDP in this study, we use the "EATMP Overall Architecture" of Eurocontrol. The EATMP overall architecture is segmented into "domains" that correspond to stakeholders' activities. Domains covered by the architecture are:

- ATM/CNS, covering ATC, ATFM and CNS functions
- Airports (air side)
- Aircraft (avionics)
- Airline Operational Cells (flight planning or dispatch activities)

In this logical architecture, "components" store data and provide services to other components or users. The architecture allocates "clusters" of components to domains. Those clusters contain specific components and instances of "cross-domain components".

The "cross domain components" are the components that are subject to various allocation schemes to stakeholders' systems. If such components are replicated, they need to be synchronised to avoid data inconsistencies. These components are:

- The "Flight Manager" (FM), which is responsible for provision of a validated, accurate and up-to-date view of flight information.
    - The "Environment Manager" (EM), responsible for both the periodic production of aeronautical information and the real time access to those data. Main data items: geographical data, airspace organisation, sectorisation data, aircraft performance, and meteorological data.
    - The "Configuration Manager" (CM), in charge of providing the current ATM configuration (actual state of dynamic airspace items, sectorisation) and the workload of the sectors.
    - The "Aircraft Derived Data Manager" (AM), which is a utility component that collects and maintains the navigation state vector and other airborne parameters for the benefit of other components.

Table 1.1 illustrates the allocation of components to clusters. Greyed cells mark cross-domain component allocation. The current understanding of the Flight Data Processing Systems, in a broad sense, is marked with a border in bold. It covers the Flight Manager in the ATC and ATFM domains, the tools that use flight data (FD) in ATC. The FDP systems also include the Aircraft Derived Data Manager and the Environment and Configuration data Managers.

Components	Domains					
	AOC	Aircraft	Airports	ATFM	ATC	CNS
Air Data Acquisition						X
Air Surveillance Server						X
Ground Data Acquisition						X
Ground Surveillance Server						X
Mobile Comms Manager						X
Air Traffic Flow Manager				X		
Load State Manager				X		
Configuration Manager (CM)	X			X	X	
Environment Manager (EM)	X	X[2]		X	X	
Flight Manager (FM)	X	X[3]	X	X	X	
Correlation Manager					X	
Arrival Manager (AMAN)					X	
Departure Manager (DMAN)					X	
Medium Term Conflict Detection (MTCD)[4]					X	
ADD (aircraft derived data) Manager (AM)	?				X	X
Short Term Conflict Manager (STCM)					X	
Controller Workstation Manager (CWM)					X	
Flight Planning	X					
Ground Operations Manager (Gate/stands)			X			
Infrastructure Manager			X			

Table 1.1: Clusters and components definition

1.4.2. FDP in ATC – FDP in our study

Although the consistency of data, functions and services is to be assured in the whole EATMP system, our study will focus mainly on the part of FDP relative to ATC (and its implication on ATFM) where the definitions given before are illustrated in figure 1.1.

Our study is concentrated on the flight data processing and not on the environment data processing (area marked in dotted line in table 1.1), around the Flight Manager.

Most of the existing FDP systems have implemented the Flight Manager and the Correlation Manager (which includes Flight Path Monitoring and is linked with the Surveillance component) only. They contain also part – if not all – of the Inter-sector Co-ordination Management, responsible for supporting the notification, co-ordination and transfer procedures between internal sectors as well as between sectors of adjacent centres.

[2] Integrated in the aircraft FMS
[3] Idem
[4] For the time being, MTCD is more a function to be defined than a component.

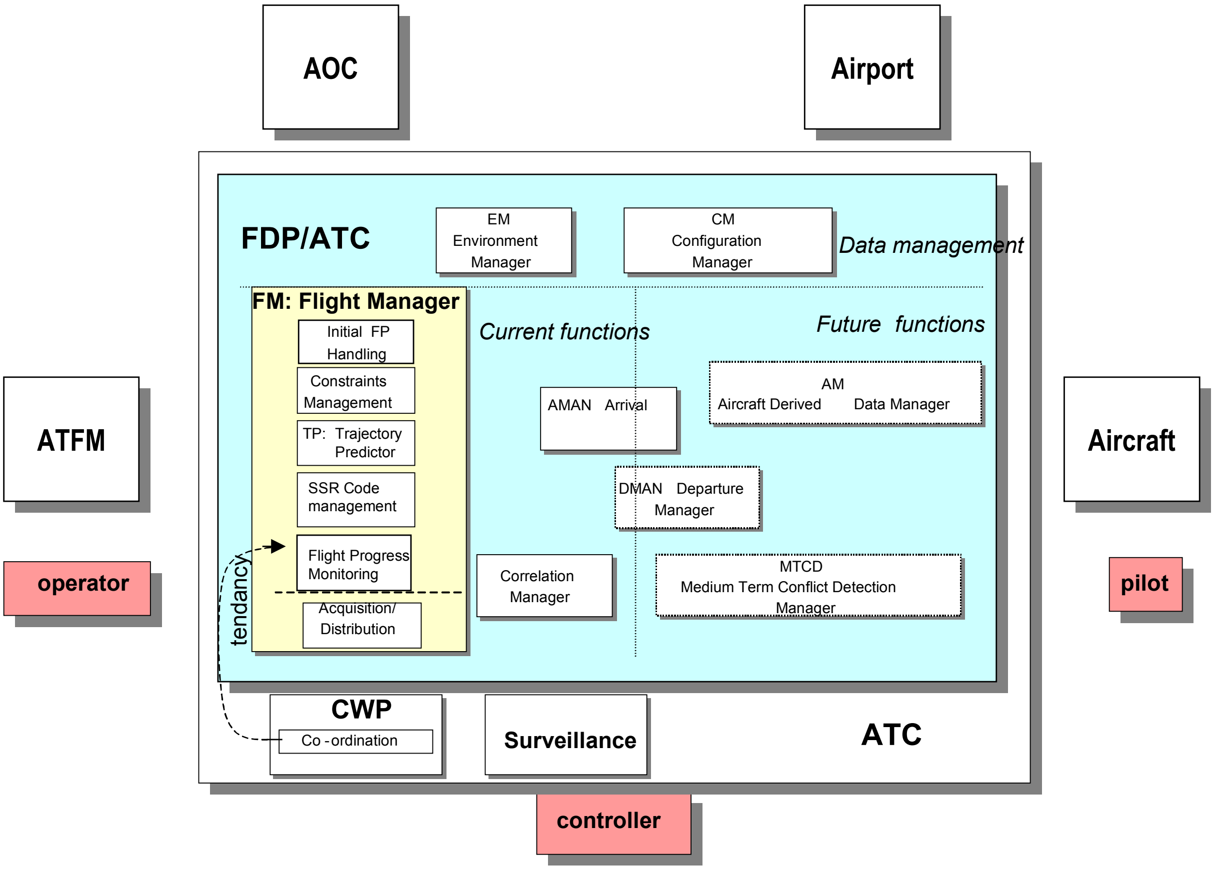


Figure 1.1: FDP/ATC components and environment

1.4.3. Flight Manager in ATC

The main data items stored by the Flight Manager are the ICAO Flight Plan, the ATFM or ATC constraints, the flight script (combination of flight plan data and constraints), the trajectory (sequence of 4D points), the posting list (set of flight data users) and the distribution rules.

The main services are data creation, retrieval and update for each data item. The dependencies between data items trigger an internal processing, to ensure the consistency of the data items related to the same flight.

The complete functionality to be supported by the Flight Manager in ATC can be split in a set of de-coupled sub-functions, namely:

- Air traffic situation determination
  - Initial Flight Plan Information management, responsible for the initial information received from the IFPS or the CWPs.
  - Route Management, responsible for the conversion of the initial route description into the corresponding sequence of points to be over-flown.
  - ATC Constraints Management, responsible for the management of the ATC strategic constraints as well as the ATC tactical constraints, including controller entries.
  - Trajectory Prediction (TP), responsible for the computation of the flight trajectory.
  - SSR Code Management, responsible for managing the allocation of SSR codes to the flights.
  - Notification Management, responsible for providing flight notification to sectors not involved in the co-ordination process but for which the flight results are of interest.
  - Civil/Military Crossings Management, responsible for managing aircraft crossing from civil to military areas or vice-versa.
  - Trajectory update based on surveillance data.

- Flight progress Monitoring.

- Flight data acquisition/distribution (acquisition of data; determination of the posting list and distribution according to distribution rules).

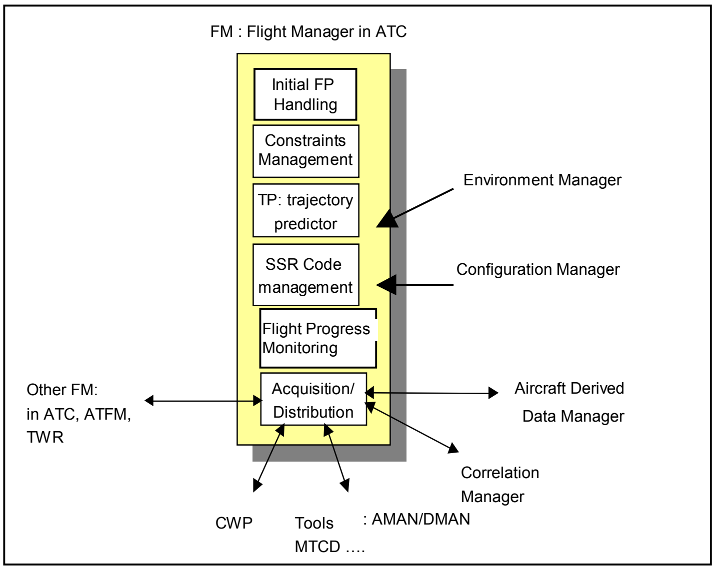


Figure 1.2: Functions of the FM

What we call here the FDP service provision is defined as:

"the provision of ATC flight manager service access points (ATC/FM SAPs) to any client in the ATM field, enabling this client to submit requests for creating, retrieving and processing flight data, according to an agreed user profile".

1.4.4. Areas of interest, responsibility, authority

An ATSU is responsible for a geographic/functional area (Area of Responsibility: AoR) but is interested in a larger area (Area of Interest: AoI), for functions that need look-ahead information. The AoI's of two adjacent ATSU overlap. The common volume is the Area of Common Interest (ACI).

An ATSU is supported by systems that have the right of creation/modification (ownership) in an Area of Authority (AoA). An Area of Authority can cover several Areas of Responsibility but only one part of an area of Interest.

The figure below illustrates AoR, AoI and ACI concepts.

If the same FM is shared by TMA1, ACC1 and ACC2 (the "clients" of the FM), the AoA of the FM would be composed of the AoR's of TMA1, ACC1 and ACC2. However, the FM would compute or retrieve from external systems flight data in the union of AoIs of TMA1, ACC1 and ACC2. Moreover, owing to consistent ECAC-wide environment data, each ATSU-level FM is able to compute an ECAC-wide trajectory if needed, bearing in mind that the interfering traffic is only known in the AOI[5].

The exchanges of data between a FM and the other ones have two purposes:

- establish the air traffic situation in the area of Interest of their "clients" in a consistent way,
- give information about the new air traffic situation including inter-sector co-ordination status (cf 1.4.2) in their areas of authority.

[5] These two possibilities for calculating an ECAC-wide trajectory give freedom in the design of systems.

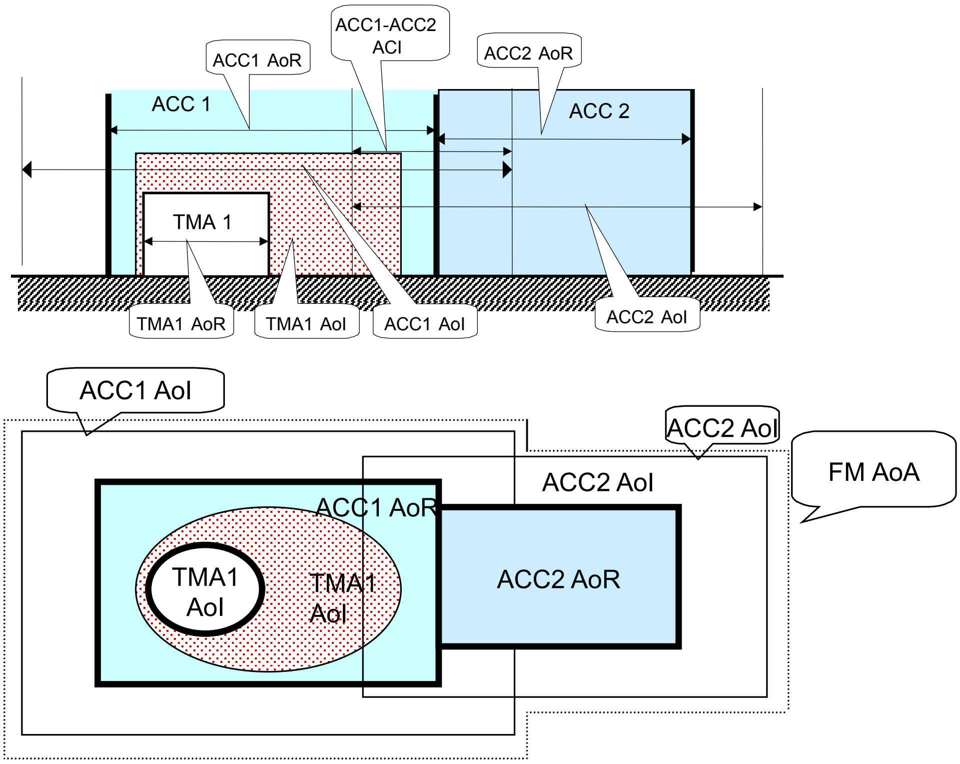


Figure 1.3: AoR, AoI and ACI

1.5. Background (General)

1.5.1. The Single Sky Initiative

ATM capacity in Europe has not followed the traffic growth rate. Airspace congestion leads to traffic delays. The available capacity is not used efficiently.

The High Level Group Report on the Single European Sky has identified the fragmentation of Air Traffic Management (airspace and systems) in Europe as one of the origins of these problems. The current approach to developing systems, which is intrinsically "national", is inefficient and costly. It often takes over a decade before a new generation ATC system is implemented successfully[6].

The root causes are essentially historical, each ATS provider wishing to fulfil its own needs, at its own rate. The procurement policy adopted by major ATC actors when the current generation of FDP systems was developed was the association of one major ATS provider with a major system supplier. This led to the fragmented market observed today, even if the number of potential suppliers has since significantly decreased.

"Investment decisions in the past often have been taken on the basis of national industrial interests with the results 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

[6] "One cannot avoid being struck by a quasi-constant phenomenon which is the very significant delays affecting the development of new centres, and notably new flight data processing systems. A two year delay is common, and a three to four year delay is far from being the exception." "There is something fundamentally wrong in the way the ATM community undertakes the development of complex systems." [C17]

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 (…). This sector has escaped the common disciplines for public procurement as a result of a lack of common standards and of exemptions to the normal legal requirements." [D1]

The High Level Group, as well as the Communication of the Commission that followed it, highlighted the need for harmonising and standardising the widely different and largely incompatible ATM Systems in use today, in a wide European perspective, in order to contribute to an increased interoperability between service providers, thereby creating the urgently necessary extra capacity.

"The development of common solutions to common problems has to be actively pursued to ensure that scarce resources are used effectively and the competitiveness of European industry in the world markets is improved."[D1]

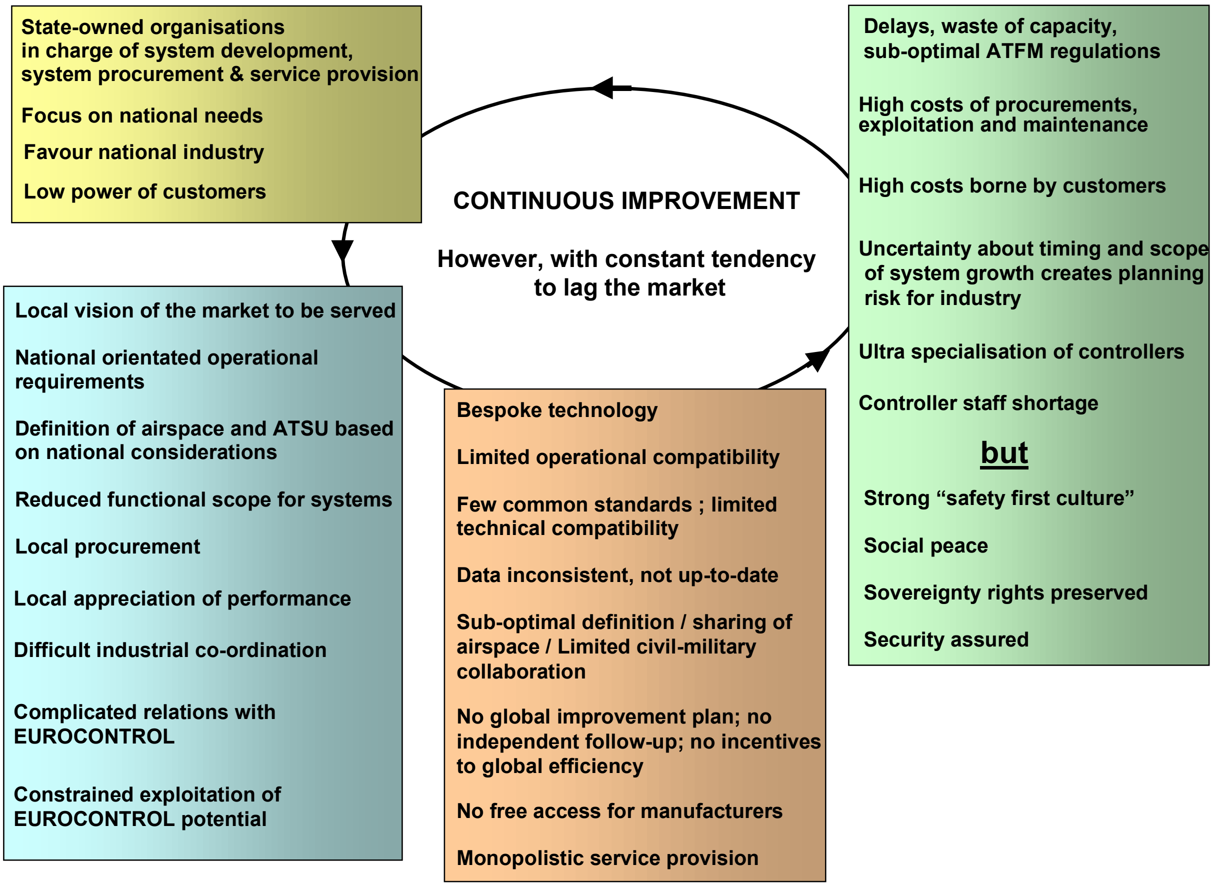


Figure 1.4: Causal relationship leading to the existing deficiencies in ATM

The High level Group Report advocated a new regulatory approach with a clearer separation between service provision and regulation, a more systematic uncoupling of ATS provision from national boundaries, an unbundling of ATM-ATS services.

Cost-effectiveness of the systems should also be a high priority.

The consolidation of the provision of ATS services and the procurement of CNS-ATM equipment and systems in the context of the emerging Single European Sky is not an easy task. It comes up against both technical and organisational difficulties, such as the intrinsic design of the existing systems and the nature and culture of organisations in place. An impulse from the Commission seems necessary.

Proposals have been made by the Commission to the European Parliament to give a regulatory frame to Air Traffic Management and are currently in discussion in the Single Sky Committee (in the European Council) [D1]:

- rules for Air Navigation Service provision according to safety and economic efficiency,
- restructuring of airspace relatively to the traffic and not the national boundaries, improvement of civil-military co-operation,
- interoperability of the European Air Traffic Management network.

1.5.2. The historical and continuing concerns of other stakeholders

Users. In 1998-9, International Air Transport Association (IATA) has produced its own analysis of the situation recommending a more centralised and liberalised ATM system in which Eurocontrol and the CEC have greater regulatory power [D9]. IATA has summarised its position in a Five Point Plan outlined below:

- Adopt the Eurocontrol "ATM Strategy for 2000+" in full;
- Give Eurocontrol and the EC greater political legitimacy;
- Establish a permanent European-wide capacity planning process;
- Liberalise the provision of air traffic services;
- Develop incentives for ATS providers to improve levels of service.

Providers. In October 1999, the Civil Air Navigation Services Organisation (CANSO) has proposed recommendation [D8] in line with the ideas of the EC and IATA. It was cautious with respect to the role that Eurocontrol could have and "would not wish Eurocontrol to be given both regulatory and decision-making powers that could be detrimental on the continued improvement of ATS provision" by the ATS providers. These recommendations are to:

- Adopt the ATM strategy for 2000+ in full
- Free service provision from political control. States should make available to service providers appropriate resources such as airspace and spectrum free from the constraints of national boundaries
- Make service providers accountable for the safety and performance of the ATM system, since they have the most direct control over meeting demand and developing the service.
- Change the current charging mechanism for ATM so as to introduce appropriate incentives for service providers to perform in terms of service value and safety.
- Establish separate regulatory authorities to protect the interests of consumers by, wherever possible and appropriate, encouraging competition whilst maintaining firm adherence to safety standards.

1.6. FDP deficiencies: a summary of basic problems and concerns

The FDPS, which is at the heart of the ATM system, illustrates the inefficiencies of current systems:

- Additional costs and risks for ATS providers (procurement, maintenance, evolution of systems, controller training),
- Difficulties and large risks for manufacturing industry,
- Public procurement rules rendered ineffective as a result of absence of common standards,
- Difficulty to move away from monolithic systems and to introduce modular techniques,
- Slowness to introduce new concepts and tools,
- No incentive for efficiency.

1.6.1. Opinions of the users

The airlines have for many years advocated the requirement for a unified system for the processing of flight data -- from the initial construction and filing of the ATC plan by the aircraft operator through all stages of its activation by the ATS provider. They consider this an essential element in maximising efficiency of the air traffic systems, whilst improving the safety and integrity of those systems. In parallel, this provides complementary efficiencies for aircraft operations.

With regard to the practical implementation of the concept, airlines have some concerns as to how this can be effectively achieved in light of certain current shortcomings in the existing organisation and provision of air traffic services. With the European ATS providers currently using such a diversity of FDPS, some of which are totally obsolete and operating far beyond their original requirements, it is difficult to understand how the concept can be introduced without some element of standardised procurement policy.

1.6.2. Interoperability and data inconsistency

Current flight data processing systems already have a high degree of interoperability in that co-ordination and transfer and data exchange between ATC centres and with military and CFMU systems is already specified at a European level and widely implemented.

The introduction of the IFPS and CFMU as common central services has increased the standardisation of ATS data exchange in Europe, and the EAD project will contribute to this trend in the future.

However, in the current European Air Traffic Management environment, there is a lack of uniformity in the calculation of planned trajectories of aircraft and in the representation of flight data. Each user of flight data – who is also most often a provider of data – e.g. Air Traffic Control Centres, Aircraft Operators, Airports, Flow Management, Military Units, Airborne Flight Management systems, etc) makes his own trajectory calculation according to his particular needs and responsibilities, leading to results which can significantly differ, owing to differences in the input data, the parameters used and the algorithms. This inconsistency leads to inefficiencies in the use of the available airspace capacity and can even lead to situations in which there may be misunderstandings between pilots and controllers about the pilot's intentions.

Further integration of ATSU's will generate requirements for a wider availability of data and the operation of ATC tools and planning of flights without consideration of the national boundaries.

Requirements for additional interoperability – between all the flight data users – arise from EATCHIP operational requirements and from concept and requirement documents being produced under EATMP, including the operational requirements identified in the eFDP Procurement Specification and the Free Route Airspace project. New ATM functions and tools may require information about trajectories of flights well beyond the current national borders and areas of responsibility (Medium Term Conflict Detection, Free routing, Arrival and Departure Manager, Multi-sector planning).

In the longer term, the likely increase in the demand for tools which support Collaborative Decision Making implies that there is a need for a virtual pool of information and, in particular, for flight data which is consistently managed and accessible to many possible users.

This lack of interoperability between systems is very often the result of heterogeneous operational procedures between ATS units and lack of commonly agreed roles of the systems (ex: IFPS, CFMU), whose functions are partly duplicated.

1.6.3. Component-based strategy

In general, the large industry suppliers like to package their offerings as integrated solutions in order to deliver the maximum value and to create competitive barriers.

To facilitate the evolution and the introduction of new tools and also to cover the needs of safety management, the service providers will need to manage large-scale integrated systems on a trusted component basis.

It is likely that safety considerations will create a need for functional, logical and physical separation of components. Each component to work in a standard environment for data interchange and to be capable of independent verification [C14/"The future Environment for ATC Service Provision and the Implications for System Procurement"/F. Agnew/NATS].

The ATC market in Europe would benefit from a shared understanding between customers and suppliers of an underlying system architecture of shared components.

1.6.4. System evolution

The introduction of new concepts and tools is a long and difficult process:

- For their system replacement, ATS providers, often influenced by consultants, overspecify requirements for concepts that are not yet mature.
- Several ATS providers specify the same functions in different ways.
- The validation of new concepts is done at the industrial phase. Getting final acceptance from controllers remains uncertain for ATS providers until the delivery of the system at the end of the process.
- The ATC market is small, very specialised and complex. Lack of visibility prevents suppliers anticipating appropriate developments and adequately planning investments.
- Existing systems (monolithic) are not very open to the addition of services.
- No commitment by ATS providers to implement concepts according to a pre-defined, gradual and agreed timeframe (e.g. ARTAS, Mode S, ADS, etc…). Eurocontrol has no power to enforce an implementation plan.

1.7. Rationale, goals, keys issues of the Study

1.7.1. Rationale

In light of the cited shortcomings of current FDP systems, especially in terms of deficient interoperability and their failure to take a European perspective, the European Commission considers the time ripe for an investigation into Europe-wide organisational and funding mechanisms and structures for the common and efficient specification of interoperable systems in the field of Flight Data Processing, their development, and provision of services based upon them.

It is in this context that DGTREN has launched the present study.

1.7.2. Goals of the study

The purpose of this study is to investigate the institutional issues for the efficient co-operation of actors in the specification, development, implementation and services provision of Flight Data Processing.

The results of this study could be used by the EC to:

- identify vision and routes of evolution towards, and final configurations of, future FDP (and later other ATM) systems (agreed on by a majority of stakeholders), including their definition, procurement, development and exploitation, in the context of the economic regulation,
- mandate Eurocontrol and/or the European standardisation bodies with clear and well defined tasks for the production of ATM standards,
- push forward the legislative and funding initiatives on interoperability and standardisation in line with strategy derived from conclusions.

The objective, by acting accordingly at the legislative level, is to:

- contribute to the solution of the flight delays and airspace capacity problems through the harmonisation and standardisation of ATM systems and FDP sub-systems, on the ground,
- stimulate the development of ATM industry by encouraging competition through the creation of standards, thereby mitigating the risks.

1.7.3. Key issues

According to the terms of reference, the study investigates:

- the technical and operational feasibility of different options concerning the FDP architecture: the problem is to demonstrate the feasibility of the scenario in terms of implementation, transition management and cost-effectiveness (chapter 2);
- the need for institutional improvement:
  - first by exploring the opinion of the stakeholders (detected insufficiencies, vision of the future organisation, possible issues) (chapter 3),
  - secondly by studying some recent projects that have been done in a collaborative way (chapter 3),
  - thirdly by reviewing the legal framework and the mandates and roles of key institutions through the current and anticipated regulatory and institutional environment (chapter 4);
- the legislative and funding initiatives that the Commission could take, taking into account the sensitivities involved, the degree of stated readiness for co-operation, the legal latitude, etc.; first FDP development and procurement have been considered; secondly an extrapolation of the conclusions applicable to any collaborative CNS/ATM systems project on an European scale has been examined (chapter 5);
- the possibility of FDP service outsourcing to “unbundle” ATC services while assuring the production and distribution of European-wide consistent Flight Data, and the specific issues resulting from such outsourcing (standardisation, data access rights, …) (chapter 6);
- the optimum process to achieve interoperability standards in the field of FDP (chapter 6.5).

One solution (defined in the term of reference of the Study) that will be investigated is the possibility to externalise some parts of the FDP from ATSU’s, more precisely the Flight Manager, in order to “unbundle” ATC services while assuring the production and distribution of European-wide consistent Flight Data.

Depending on the level where the externalisation is done, several organisational and technical scenarios are possible: it could lead to an externalisation of some parts of the FDP service that could be outsourced by a third party.

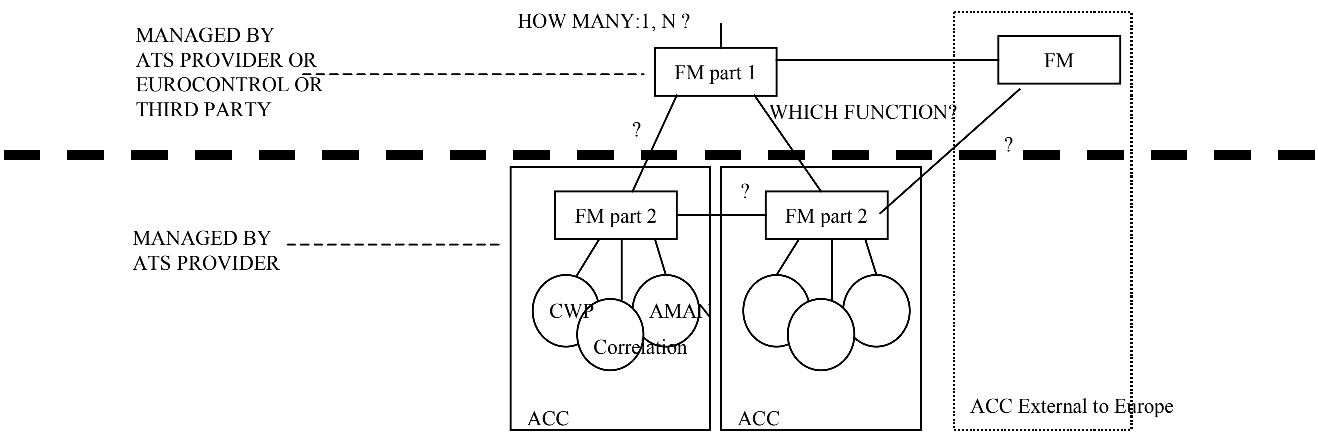


Figure 1.5: Externalisation of some parts of the FM

1.8. Approach, methodology

1.8.1. General

Linked to the key issues described before, the successive steps of this study were the following:

- explore possible FDP system architectures (WP1),
- explore the stakeholders opinions on a future FDP architecture, on institutional issues, the need for improvement, the possible solutions (WP2),
- take experience from past projects done in a collaborative way, review the present and anticipated legal framework applicable to FDP (WP4),
- propose recommendations for legislative and funding initiatives, to answer to the problems that have been detected, taking into account the opinions of the stakeholders, the experience of the past, the present and anticipated regulation, first for FDP (WP2), secondly for collaborative projects in CNS/ATM (WP4),
- in parallel, study the possibility to unbundle FDP services and the specific issues resulting from this outsourcing (WP3),
- finally, define the optimum process for standardisation in the FD domain (WP5).

We develop some points below.

1.8.2. Exploring FDP system architectures

In order to improve the operational and technical compatibility of FDP systems in Europe and to introduce more efficiently new concepts and new technology, a new policy could be built around FDP development and service provision. This policy is one input for the definition of the architecture of future FDP systems. On the other hand, the new policy is constrained by technical feasibility, legacy systems and current organisation.

The engineering process sustaining the definition and implementation of interoperable systems, including the FDPS, can be decomposed into several steps starting from the definition of the operational concept up to the exploitation of equipment supporting the services delivered to end users.

A more efficient and seamless service at European scale implies a more intensive collaboration between the involved stakeholders, possibly encouraged by a reconsidered institutional framework. This involvement may take various forms depending on the stage of the system life cycle concerned.

The new architecture and the underlying organisation shall take account of legacy infrastructure and systems, as they cannot be defined from scratch.

Our position is that a top-down approach to define organisations and systems cannot be conducted in total abstraction from existing organisations and systems. In ATM, nothing ever starts from a green field and we do not believe that a big bang approach has any chance of succeeding. Whatever could be the user requirements, we will have always the choice between centralised and distributed systems and this choice is not independent of the organisation that is put in place.

One of the virtues of doing some initial work on the architecture is to make us think harder and concretely on the practicalities of any organisational scheme, rather than just asking what is the best organisation to make this or that technical scenario work.

1.8.3. Involvement of the stakeholders

The involvement of stakeholders is fundamental to the success of this type of study.

Having defined several scenarios based on possible FDP system architectures – to kick start the discussion on a practical and concrete basis – a set of stakeholders has been consulted on their views on organisational, funding and other institutional issues. The points to which the survey was expected to give responses can be summarised by 3 questions to stakeholders:

- which insufficiencies they acknowledge in the existing regulation and organisation?
- what is their vision or preferred model of the future organisation and the future FDP systems (improvements, radical changes)?
- what are the possible issues to be solved by that new organisation and how they can be solved?

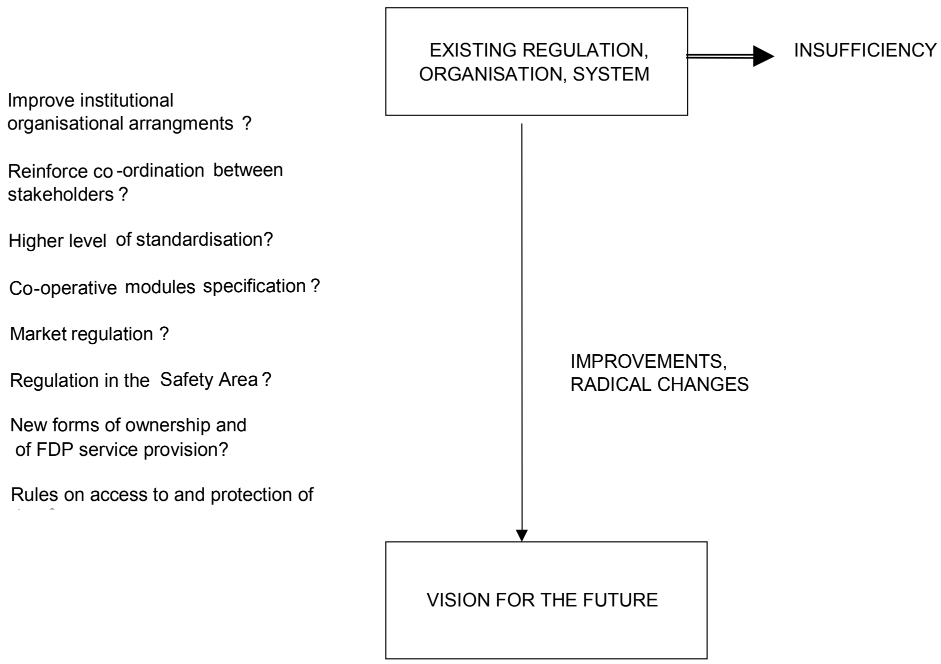


Figure 1.6: Stakeholders' vision for the future

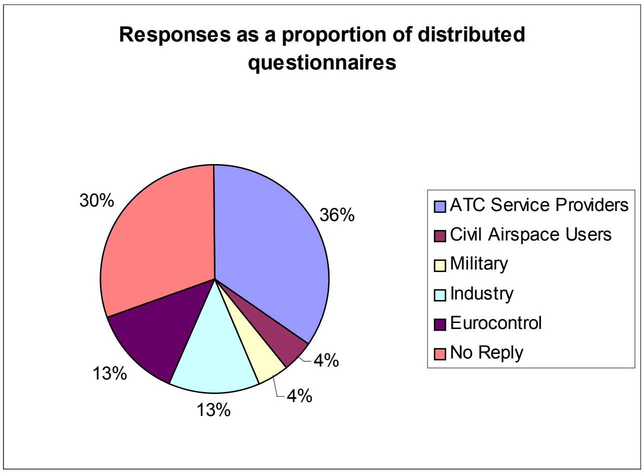
A detailed questionnaire was sent to a panel of experts from different types of organisations, mainly ATSPs, industry and Eurocontrol (see annex A). For practical reasons, airlines and airports have been approached only through their associations (IATA, IACA, ACI), and the military viewpoint was obtained from EMEU experts even if they did not represent officially any military organisation.

As far as the general approach to the survey is concerned, respondents were encouraged to express their personal opinion freely (they remained anonymous). The answers do not necessarily reflect the official view of organisation, but the whole makes up an irreplaceable source of information based on experience and background of people of the trade.

The following organisations have filled in the questionnaire:

- ATC Service Providers: AENA, Austro Control Gmbh, DFS, DNA, ENAV, NATS, NAV Portugal, Skyguide;
- Civil Airspace Users: IATA;
- Industry: INDRA, Lockheed Martin, THALES;
- Eurocontrol: EEC, Regulatory unit, CFMU;
- Military: EMEU.

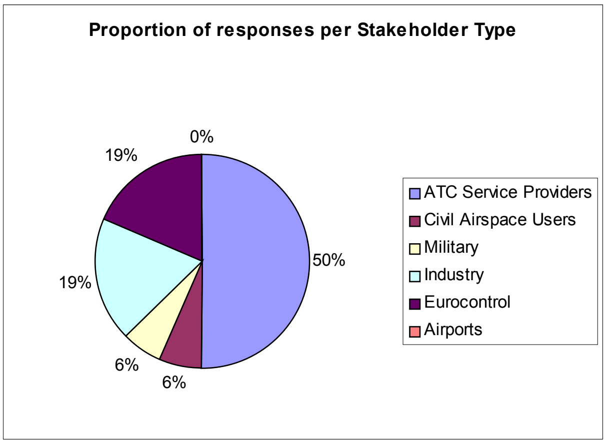
The diagram below shows the distribution of responses as a proportion of distributed questionnaires.



The return rate proved to be quite satisfactory, 16 responses having been received out of the circulated 23 questionnaires.

The ATSPs responded massively (8 out of 12) which goes to show that this is really a key issue for them. User views were received from IATA.. Unfortunately, the collated views of airports could not be obtained.

Considering only the returned questionnaires, the distribution of responses per type of stakeholder is the following:



The sample shows a strong supply side perspective, providers, Industry, Eurocontrol.

Furthermore, a workshop was held on January 9th 2002 to present the preliminary results of the study. The feedback obtained was used to refine the work and contribute to the final conclusions.

2. DEFINITION OF FDP DEVELOPMENT OPTIONS

2.1. Statement of work

2.1.1. Objectives

The objectives of the work package are to define several alternatives for the overall architecture of the future federation of FDP systems in Europe, assess these alternatives against different technical, operational and economical criteria, conduct a first assessment of the impact of architectural choices into other areas.

Special care will be taken with the ECAC-wide and consistent FD provision requirements and with a transition plan to implement these requirements in the medium term starting from the current and foreseen legacy ATM systems (CFMU, IFPS, FDPS…).

2.1.2. Working assumptions

We assume that the timeframe of the study is broadly the same as the timeframe of the current Eurocontrol ATM strategy for the years 2000+ [C3].

Consequently, operational improvements (OI's) related to FDP functions, as described in [C3], are to be supported by the FDP system architecture. The "Provision of Consistent Flight Data" OI is added to the current list of OI's.

2.1.3. Approach

The approach is based on the initial definition of a target ATM/CNS logical architecture, leading to the derivation of potential architectures using various allocation schemes from functionality to systems, followed by an assessment of each one of those potential architectures including transition plans.

Concurrently, an architecture section is incorporated in the questionnaire submitted to the stakeholders, so as to collect their preferences. The feedback from the stakeholders helps evaluate the relative importance of architecture alternatives from the stakeholders' viewpoint.

2.1.3.1. Definition of potential architectures

The main tasks are listed below:

- To select a reference logical model, since there is no need to build "yet another CNS/ATM model". The reference for the logical model is the EATMP Overall Architecture of Eurocontrol (reference C12, hereafter-denoted EOA). This architecture is arguably the most comprehensive synthesis available today. In the EOA, the logical model is defined by clustering functions and data into so-called "components".
- To define potential architectures. The components of the logical architecture are allocated to systems located in/operated by ATS units and other participating organisations, depending on the applied scenario. The three main scenarios for flight data management are broadly sketched below:
  - A network of enhanced local systems, located in ATC units, but "open enough" to provide data to non-ATC users and compliant with more stringent consistency requirements with other ATSUs.
  - A fully centralised architecture, whereby data and services are available at one (or a few) locations in the ECAC region.
  - A network of enhanced local systems, located in ATS units, with a central data warehouse, whereby data that result from local processing in the nodes of the network (for example ATSUs, CFMU) are made available in the whole ECAC region.
- To define technical architectures, in the sense of candidate technical frameworks for the overall system. This includes the following subtasks:

  - To identify the leading technologies for integrating large scale systems, according to the degree of coupling (loose versus tight),
  - To identify the specific responses to problems like data sharing and consistency management, location transparency, scalability and capacity planning, dependability (reliability, availability, maintainability, safety).

- To define the transition path from current systems to the target ones. This task determines the roadmaps from the current situation to each of the target configurations. As a side effect, cost and risk attached to the transition are identified for the assessment of architectures.

2.1.3.2. Assessment of architectures

The objective of this second part of this chapter consists in determining a set of criteria for evaluating the alternatives and then assigning figures of merit to these alternatives, reflecting the specific design of each one of them.

In the case of the FDP architectures, some criteria are broadly outlined in section 4.1 of document [A3]:

- Intrinsic qualities of the architectures. We assume that "functional model" in [A3] refers to the alternatives described in the present document. The criteria here are those that apply to usual system engineering under the "system effectiveness" header: performance, operational availability, supportability, etc.
- Economic criteria: Potential economies of scale, of a single co-ordinated effort.
- Institutional criteria: Modalities of ownership, data ownership and distribution.

The set of criteria and the way to relate them to properties of the architectures will be examined and the resulting evaluation model will be populated for the technical dimension (including the direct economic and institutional aspects).

Risk assessment will be incorporated in the evaluation model, in the appropriate domains. For instance, technical risks will be part of the system engineering viewpoint.

2.2. Determination of architecture alternatives

2.2.1. Scope

In the present study, the scope is restricted to the FDP systems in the ATM field. Consequently, we do not address:

- The operational discrepancies, in the sense of the day-to-day control procedures that often differ between ATSUs.
- The discrepancies related to non-FDP subsystems, according to the definition of FDP given in chapter 1. In particular, the fact that Controller Working Positions are different between ATSUs entails limitations in operational compatibility.

The alternatives that have been investigated mitigate the "low interoperability" cause of the observed problems. There are two orthogonal sub-problems:

- The interoperability between different kinds of stakeholders: AOC with aircraft, AOC with ATM, ATM with aircraft. The relation between AOC and aircraft is not investigated. The interactions between AOC and ATM and between aircraft and ATM are considered, but do not change significantly from one scenario to the next.
- The interoperability between instances of the same kind of stakeholders. Aircraft and AOC are not investigated further[7]. The focus is put on the interoperability between ATM systems.

[7] In the future, the capability for aircraft to broadcast flight data to other aircraft through ADS-B is likely to change control procedures in some airspace regions, but the standardisation of ADS-B services is assumed to be enforced from the very beginning. It should be noted that ADS-B is a surveillance system first, despite the capability to transmit flight intentions.

2.2.2. Logical architecture

The components that constitute the logical architecture have been described in chapter 1. For the architecture alternatives, the components that are considered are:

- The Flight manager (FM)
- The Environment Manager (EM)
- The Configuration Manager (CM)
- The Aircraft Derived Data Manager (AM)

2.2.3. Baseline for FDP potential architectures definition

Whatever the technology used for each target architecture, there will be several systems deployed on different sites, connected by different networks, according to an overall distribution scheme over the ECAC region. According to the technical framework survey presented in Annex D.4, the systems will fall into one of the following classes:

- Operational systems, which provide the services described in the logical architecture and manage the corresponding data. When operational data are replicated in several places, one operational system holds a master copy and other hold secondary copies, according to data ownership rules.
- Data warehouse systems, which retrieve data from other nodes, to build a consolidated new database, applying if needed data fusion principles to solve heterogeneity issues. The new database is made available to client systems for further processing.

The scenarios are related to the allocation of data and services from the logical architecture to various physical distribution schemes, in terms of:

- Sites (for ATS):
  - Local units: ACC, APP, TWR control centres;
  - National units: National Airspace Management Cells, AIM authority;
  - Regional ATS units: IFPS Haren/Bretigny, CFMU Haren
- Scope: Sector, ATS unit, region, world.

We take for granted the existing or planned European central systems: IFPS, EAD, ETFMS (which incorporates the current TACT system).

In our scenarios, the ADD (Aircraft Derived Data) Manager is strongly connected to the Flight Manager in ATSUs in order to cover air-ground Flight Data consistency.

We consider that the surveillance segment is sufficiently flexible to be adapted to any scenario, in most cases co-located with the Flight Manager.

Although there is a strong relationship between environment data, configuration data and flight data, for the sake of simplicity, we present alternatives in terms of allocation of Flight Manager (FM) instances to units.

The main scenarios identified are, in loose terms:

- A “flat” network of enhanced peer systems, located in ATC units, but “open enough” to provide data to non-ATC users and compliant with more stringent consistency requirements with other ATSUs.
- A centralised architecture for en-route ATC, whereby data and services are available at one (or a few) locations in the ECAC region. Major TMAs are served by a local ATSU for APP/TWR ATC.
- A compound architecture with a network of local systems and a central data warehouse, whereby data that result from local processing are made available in the whole ECAC region.

These scenarios with second-order options are detailed in the following sections.

We recall that the scenarios describe the sketches of the physical architectures that result from allocating logical components (as defined by the EATMP overall architecture) to sites and scope, especially the FM component. However, the physical architecture of each scenario is only one solution to the allocation problem and other solutions are equally feasible. In fact scenarios can be mixed in the ECAC region, especially during transition.

We can illustrate the set of theoretical solutions by the following examples, limited to the ATM sites.

Figure 2.1 depicts a scope structure in a region that is composed of several FIR's, themselves partitioned into en-route airspace and several TMA's. The ATFM FM is located into one node and covers the whole Region.

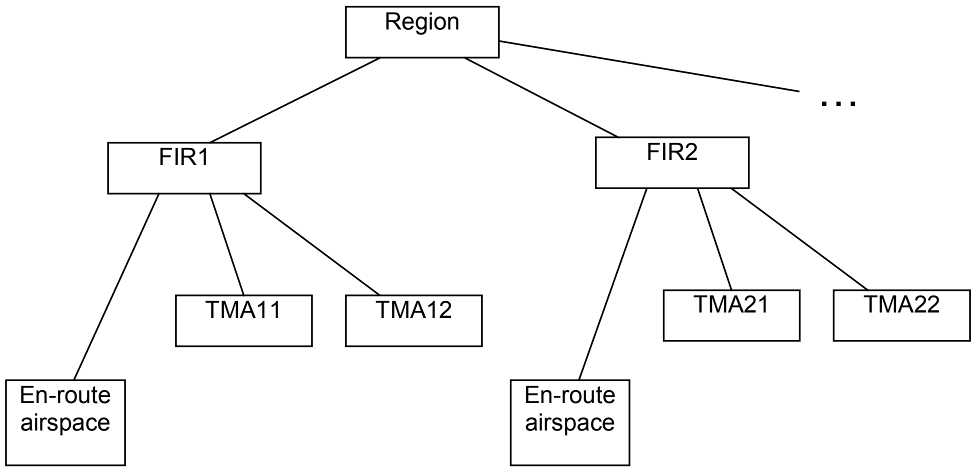


Figure 2.1: A scope structure

The following figures give possible definition of FM Area of Authority (defined in 1.4.4) relatively to the Areas of Responsibility of the sites. We suppose here that we have one FM by ATSU.

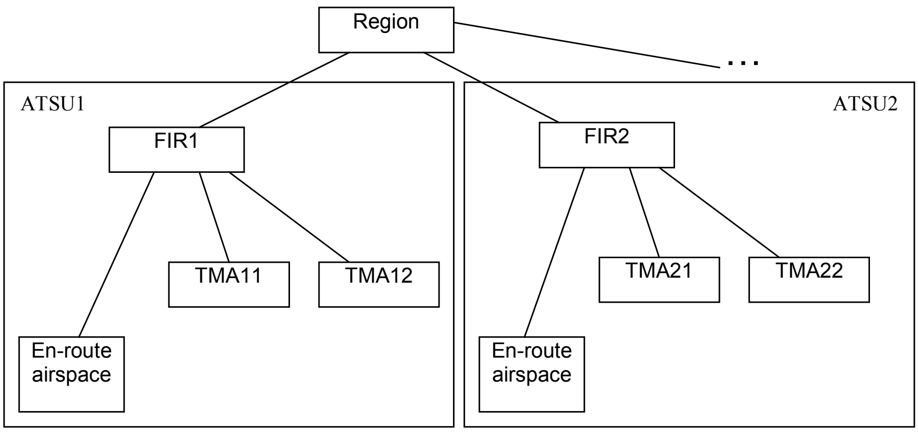


Figure 2.2: Classical FM allocation to ATC centres covering one FIR.

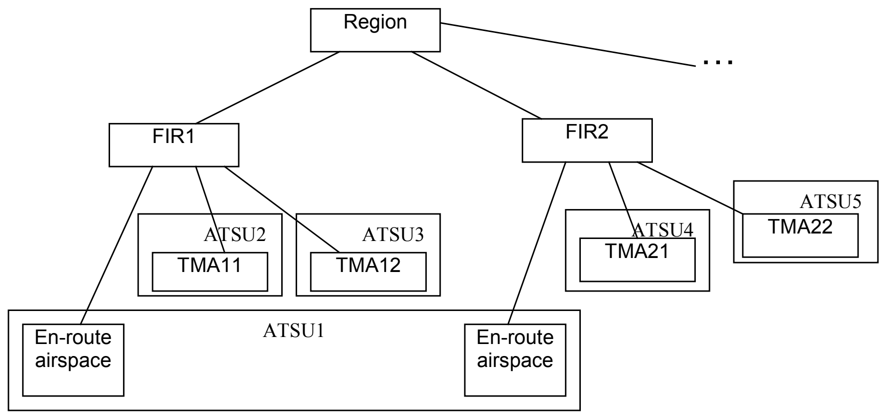


Figure 2.3: Another allocation solution with one FM for en-route control and one FM per TMA (APP/TWR control).

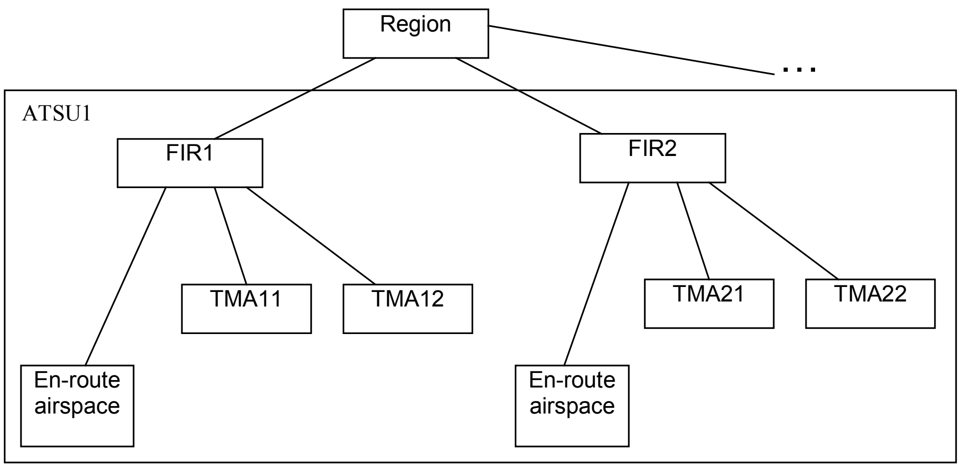


Figure 2.4: A sub-regional allocation solution with one FM for two FIR's.

In order to prevent some possible misunderstanding, we do not use the concept of a "logical central FM" implemented by distributed physical FM nodes, as proposed for instance by the EFDAS approach (C1). We distinguish two base cases:

- The "replication" case. There is one single specification of a system that is implemented and then fielded in several physical instances, either in the same location or in remote locations, for load sharing and dependability reasons. Two sub cases can be considered:
    - The "simple replication" case. There is only one implementation, and all instances are clones of this implementation. This means, in practice, that there is only one development programme. IFPS is an example of this subcase.
    - The "n-version replication" case. There are two (or more) different implementations that conform to the same specification. This is the n-version development policy that is mostly used for avoiding design and programming common cause failure in software-based safety critical systems. This means that there are as many development programmes as versions.
- The "federation" case. There are several separate specifications of systems and one common specification for interoperability between those systems so as to ensure that the instances of the various systems can interoperate in accordance with the specification.

Coming back to the EFDAS case, if the physical FM nodes come from different specifications, we fall in the federation case, otherwise we fall in the replication case.

2.2.4. Scenario 1: Flat network of peer systems

Figure 2.5 illustrates the overall architecture of this scenario.

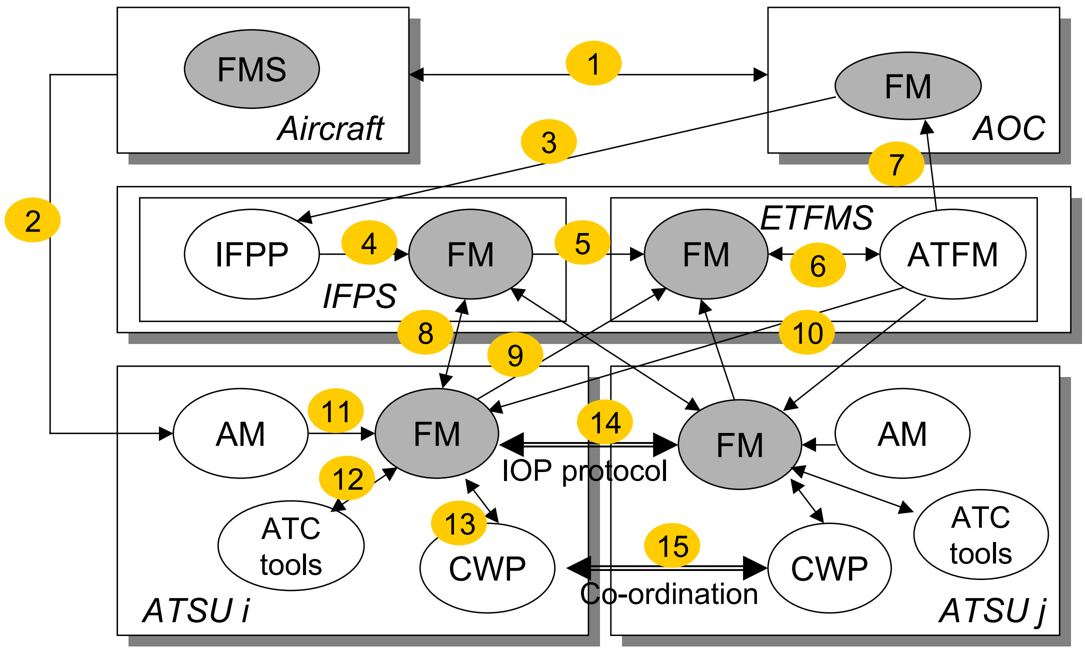


Figure 2.5: Scenario 1: Flat network of peer systems

The flows in the architecture are listed in the table below

#	Between	And	Flow
1	AOC/FM	Aircraft/FM	FPL/ In-flight report
2	Aircraft/FMS	ATSU/AM	Aircraft down-linked parameters
3	AOC/FM	IFPS/IFPP	FPL (ICAO definition)
4	IFPS/IFPP	IFPS/FM	Validated FPL
5	IFPS/FM	ETFMS/FM	FPL
6	ETFMS/FM	ETFMS/ATFM	FD/ 4D constraints on airspace resources
7	ETFMS/ATFM	AOC/FM	Departure slot & point profile
8	IFPS/FM	ATSU/FM	FPL
9	ATSU/FM	ETFMS/FM	FD update, Position report
10	ETFMS/ATFM	ATSU/FM	Departure Slot, point and airspace profiles
11	ATSU/AM	ATSU/FM	ADD (Aircraft Derived Data)
12	ATSU/FM	ATC tools	FD / FD update request
13	ATSU/FM	CWP	FD / FD update request
14	ATSU i/FM	ATSU j/FM	FD in ACI, FD update events
15	ATSU i/CWP	ATSU j/CWP	Co-ordination events

Scenario 1 is an improvement of the current architecture in the ECAC region. The synchronisation of FM components is required to provide FD consistency across systems.

The FD consistency is obtained through:

- An improvement of official publications specifying conditions of use of airspace and route network, the use of common concepts and terminology on an European scale,
- The consolidation at an European level of the environment and configuration data (including cross-border management), offering an easy access point[8],

[8] This is like EAD in essence, but extended to include dynamic data.

- A higher quality of flight data, static and dynamic environment data exchanges between all the stakeholders (including air-ground). The flight data that are to be exchanged would become significantly more accurate, including both the flight script and the computed 4D trajectory.

The flight script is described in the EOA [C12] document (section 5.14.1 of the Strawman version). In short, the flight script bridges the gap between the ICAO flight plan and the on-board FMS navigation plan. The flight script combines what could be called the “expanded” flight plan and the constraints imposed to the flight. The expanded flight plan is a sequence of manoeuvres that result from the horizontal navigation plan and the vertical reference profile of the flight. The 4D trajectory is computed by simulating the flight with a flight dynamic model and forecast weather data, executing each manoeuvre of the flight script while satisfying all applicable constraints.

The Areas of Interest (AoI) of ATSUs are extended to cover ATSUs’ needs concerning the new tools which are implemented locally (e.g. MTCD that detect potential conflicts beyond the border). Each FM calculates the trajectory for one or several AoI (e.g. en-route airspace + TMAs). In other terms, FM could be local or regional. As the AoIs of two adjacent ATSUs overlap, the trajectories calculated by the two FM could be different. Exchanges between ATSUs allow a better consistency but do not guarantee identity of results. Correlation and flight path monitoring are co-located with the FM. The FM monitors the distribution of FD to the ATC tools and other clients.

Inside an ATSU, a distributed and modular architecture with standardised interfaces is adopted.

ETFMS (phase 2) provides “a complete picture of predicted traffic”: this view could be less accurate and less frequently updated than the view of each ATSU. No other node than ETFMS is devoted to making European-wide FD available in this basic scenario.

Regarding the environment data, the AIP data are under the responsibility of states. They are usually managed at a national level for sovereignty reasons, thus leading to one Environment Manager (EM) node per state. AIP management could also be delegated to a central unit (e.g. for not yet equipped countries). For these countries, one regional EM would provide AIP services and local AIP operators would use client workstations connected to this central system. This is actually an EAD option.

A potential upgrade to this scenario is obtained if the co-operation between peer FM’s in ATSU’s is raised to a level where transparent access to a remote FM could be possible when the local FM is not able to provide the expected service (either data are out of the local scope, or the FM is unavailable). This means that data can be made available to more than one FM, leading to some kind of data replication or sharing among FM’s.

2.2.5. Scenario 2: Centralised en-route system

Figure 2.6 illustrates the overall architecture of this scenario.

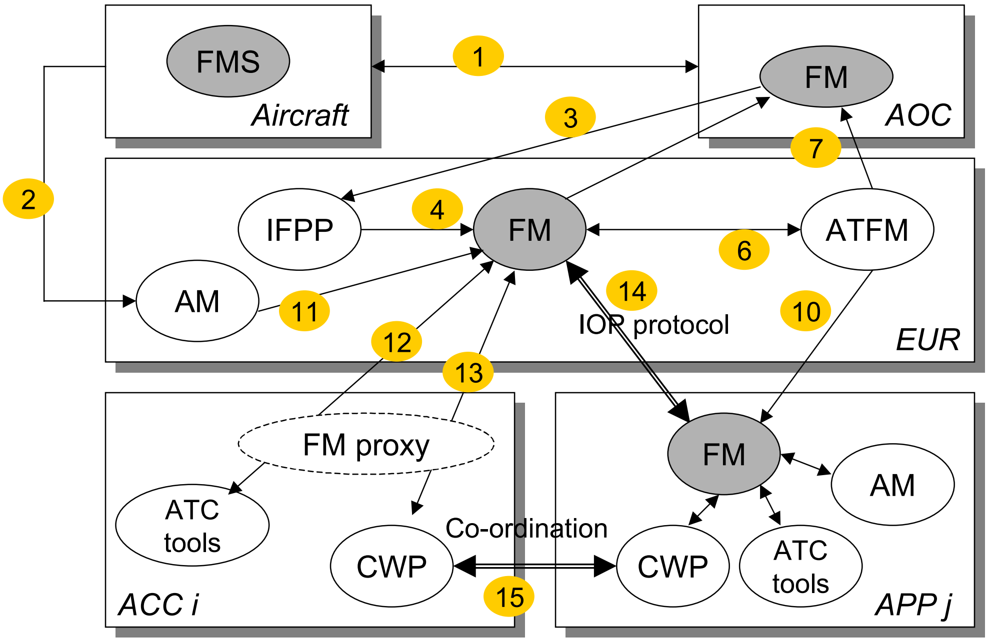


Figure 2.6: Scenario 2: Centralised en-route ATC

The flows in the architecture are listed in the table below:

#	Between	And	Flow
1	AOC/FM	Aircraft/FM	FPL/ In-flight report
2	Aircraft/FMS	ATSU/AM	Aircraft down-linked parameters
3	AOC/FM	IFPS/IFPP	FPL (ICAO definition)
4	EUR/IFPP	EUR/FM	Validated FPL
6	EUR/FM	EUR/ATFM	FD/ 4D constraints on airspace resources
7	EUR/ATFM	AOC/FM	Departure slot & point profile
10	EUR/ATFM	APP/FM	Departure Slot, point and airspace profiles
11	EUR/AM	EUR/FM	ADD (Aircraft Derived Data)
12	EUR/FM	ACC/ATC tools	FD / FD update request
13	EUR/FM	ACC/CWP	FD / FD update request
14	EUR/FM	APP/FM	FPL, FD in ACI, FD update events
15	ACC/CWP	APP/CWP	Co-ordination events

Scenario 2 takes into account several facts and trends

- Current en-route ATC in the ECAC region is distributed over an excessive number of small ACC's, essentially for historical sovereignty reasons.
- There is a clear trend toward the creation of regional ACC's for upper airspace control.
- Busy TMA's are complex areas, which justify local systems tailored for managing special configuration (e.g. multi-airport approaches and departure patterns), whereas en-route airspace is more uniform in nature.

- The increase of aircraft autonomy in en-route airspace alleviates en-route ground control workload and pushes for larger AoR's per ACC, and a prominent role for TMA control[9].

This leads to a potential target situation with:

- A set of APP/TWR control systems centred on busy TMA's
- A few ACC's served by one centralised or a few tightly coupled systems.

The depicted scenario features one centralised FM, shared by en-route ATC and ATFM.

FD consistency is obtained through the centralisation of Flight Management, Environment Management and Configuration Management for the en-route airspace of the whole ECAC region. For terminal airspace, the scenario is similar to scenario 1. The en-route Flight Management is strongly connected with the initial flight data processing and with the slot allocation process. There is a unique view of the flight for the en-route part, which can be delivered to external systems as well as the environment and configuration data.

The architecture may be physically distributed over a few sites for the sake of dependability and for load sharing in normal operation. There could be several ACC FM nodes, each one being responsible for one fraction of the traffic, computing the whole trajectory of flights, otherwise this would be equivalent to scenario 1. The slot allocation process, central by nature, would be located in one site, with other sites providing fallback support.

The working positions are located in several centres, independently of the FM. Data caching in proxy servers would cater for performance issues (e.g. WAN traversal latency). The tactical tools are co-located with the CWP, with clear interfaces with FM through the proxies. In any case, the number of ACC's is significantly reduced. The proxy server can also handle the eligibility and distribution rules.

2.2.6. Scenario 3: Compound system

Figure 2.7 illustrates the overall architecture of this scenario.

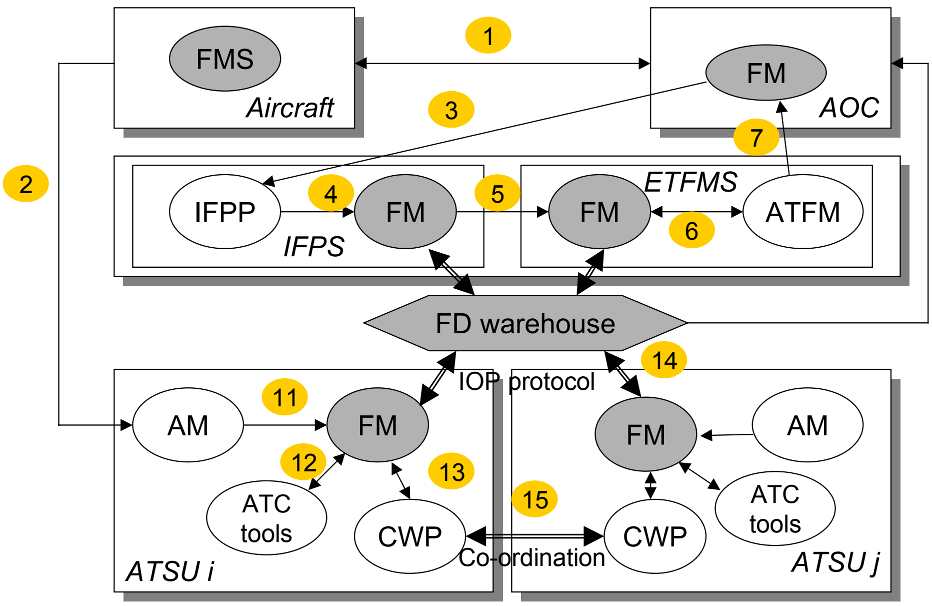


Figure 2.7: Scenario 3: Compound architecture

The flows in the architecture are listed in the table below.

[9] See for instance the AFAS concept as described in EC DG TREN. AFAS (Aircraft in the Future ATM System). WP1.4. Operational Services and Environment Definition (OSED). V2.1 August 2001.

#	Between	And	Flow
1	AOC/FM	Aircraft/FM	FPL/ In-flight report
2	Aircraft/FMS	ATSU/AM	Aircraft down-linked parameters
3	AOC/FM	IFPS/IFPP	FPL (ICAO definition)
4	IFPS/IFPP	IFPS/FM	Validated FPL
5	IFPS/FM	ETFMS/FM	FPL
6	ETFMS/FM	ETFMS/ATFM	FD/ 4D constraints on airspace resources
7	ETFMS/ATFM	AOC/FM	Departure slot & point profile
11	ATSU/AM	ATSU/FM	ADD (Aircraft Derived Data)
12	ATSU/FM	ATC tools	FD / FD update request
13	ATSU/FM	CWP	FD / FD update request
14	ATSU/FM	FD warehouse	FD in AoR, FD update events, slots, IFPL and other data and events needed for FM synchronisation
15	ATSU i/CWP	ATSU j/CWP	Co-ordination events

In this scenario, the notion of ECAC-wide Flight Data continuity is introduced. The airspace is divided into Areas of Authority (AoA), each of them devoted to a FM which is a node participating in the provision of the continuity service. Each FM calculates the trajectory in its AoA.

For providing ECAC-wide FD, especially the trajectory of a flight, a merging and/or aggregation of partial data, provided by each FM has to be performed. The responsibility for performing this aggregation is centralised in a dedicated system called the Flight Data warehouse.

This dedicated node does not interfere with local FD processing. In addition, the data warehouse would not re-compute any data, but apply merging and aggregation rules on provided partial data. It is assumed that a sufficient level of interoperability between FM's guarantees that inconsistent partial data are unlikely to be transmitted to (or retrieved by) the data warehouse.

In any case, the flight data computation location is transparent to clients. Clients ask for a global service that returns a unique and complete data set including either or both the flight script and the trajectory for a flight.

Beside ECAC-wide data provision, the data warehouse is intended to play the role of a central interoperability (IOP) node, in the form of a message broker (see technical annex for message broker description). This broker handles flight data exchange and event notification between ATSU FM's and between ATFM and ATSU FM's.

The FD warehouse may be physically distributed over a few sites for the sake of dependability and for load sharing in normal operation.

The tools and other functions connected with the FM are highly modular with standardised interfaces. According to its AoA, the FM could be local or regional.

There are two principal differences when compared with scenario 1:

- A trajectory continuity service is provided to FD users across the ECAC area. In other words, the AoI of a client system is no longer restricted by the scope of the local FM.
- The whole trajectory is calculated by one single system, which handles potential consistency issues for the client. (In scenario 1, the client system has to perform data fusion itself)

Figure 2.8 describes the role of the data warehouse for FD provision. The data warehouse is notified of trajectory creation and update by the originating FM's The data warehouse concatenates segments upon each notification whenever possible. When a client submits a request for a global trajectory, the data warehouse retrieves the whole trajectory at once in its current state.

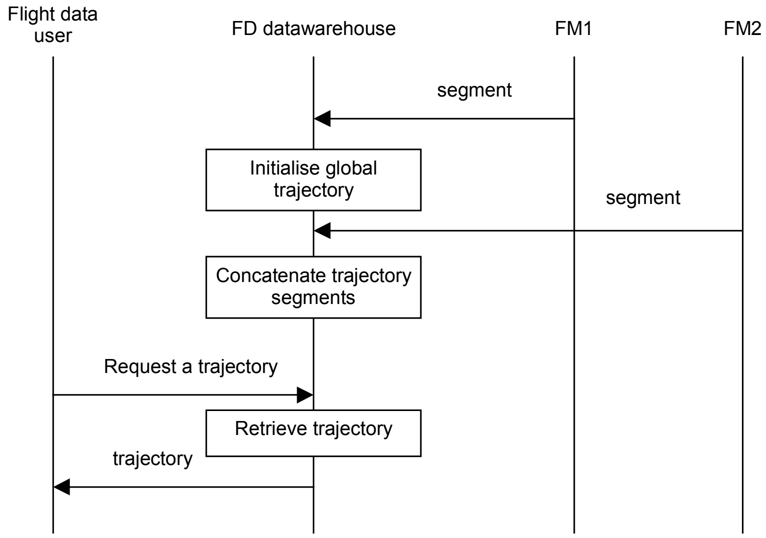


Figure 2.8: Centralised fusion and distribution of flight data.

Since there is one node (either local or central) capable of providing an ECAC-wide trajectory, it seems that there is no longer a need for a separate FM in the ATFM cluster – trajectories could be retrieved from the former node. In fact, this is not desirable, owing to the slot allocation process. The slot allocation process is tightly coupled with trajectory prediction. Even if the current TACT/CASA algorithm is likely to evolve, the concept will remain quite similar to the current one: there is a set of constraint points in the congested airspace, where arrival rates are limited. Flights that pass over such points get "internal slots" (thus incurring delays), that have to be consistent with the flight overall execution[10]. In the current CASA algorithm, the most penalising slot along a flight path determines the departure slot to be applied to a flight. The departure slot results from the other internal slots (that are hidden to non-ATFM systems). This is a complex scheduling algorithm over hundreds of flights that compete for internal slots. Looking at the internals of Trajectory Prediction (TP), there is an iterative process that inserts 4D constraints in the flight script of all regulated flights, computes the trajectories and checks that they are feasible[11]. This is a computation-intensive process that cannot be efficiently distributed over a wide area network.

It is worth noting that the problem does not occur in the second scenario, because ATFM and en-route ATC share the same FM. This FM can be featured with an internal TP server that computes ECAC-wide trajectories for both kinds of users. However, in the second scenario, there is still an issue, due to the distribution of flight data over TMA FMs and the en-route FM. Boundary conditions shall be satisfied at the TMA exit/entry points for the en-route schedule and the TMA schedule[12].

[10] The flight time between two constraint points cannot be reduced or expanded arbitrarily, when changing the slot over each point. In principle it should be constant, meaning that the flight keeps the preferred speed on the flight path between these points. In other words, the sequence of slots over points along the flight path should preserve the time interval between the slots, and the sequence should be translated globally along the time axis until slots are available at each point for the flight. In addition, upon time translation, some parts of the flight path can change due to airspace state change, or the arrival rates can also change.

[11] in the current CASA algorithm, the requested cruise speed and RFL are preserved. In practice, the flight is increasingly delayed until a sequence of slots over all congested points is found. This might change in the future, if a generalised slot allocation process is implemented, harmonising arrival, en-route and departure slots, and speed constraints, that introduce more flexibility in the scheduling process, are determined.

[12] In the AFAS concept, this boundary condition, called Required Time of Arrival (RTA), becomes the "contract" between the aircraft and ATC.

2.2.7. Transition path

In this section, transition path description tackles only the technical aspects of the migration from the present system topology to the target outlined in each scenario. Obviously, institutional issues may impair technically feasible options.

2.2.7.1. Scenario 1

Scenario 1 does not change the overall topology of current systems. It is indeed the baseline scenario. The emphasis is put on the improvement of interoperability in the sense of data consistency across systems.

The transition plan is somewhat similar to what has been done for establishing the OLDI co-ordination protocol between ATSU's, or the IFPS and TACT protocols between the CFMU and the ATSU's and AOC's. However, the scope is enlarged with aircraft airborne systems and Airports, in a comprehensive way.

- The data that need to be synchronised are identified and specified in the form of a data exchange standard. In the vein of OLDI messages, a catalogue of data items and message production rules is defined.
- The operational processes for keeping data consistent upon data creation or update events in any situation are defined, leading to system requirements.
- The existing systems are fitted with additional protocol handlers, in the course of evolutionary maintenance activities.
- Client systems that need ECAC-wide FD have to implement the logic for data retrieval from FM's, EM's and CM's, as appropriate, and perform data fusion for building aggregate data sets.

2.2.7.2. Scenario 2

Scenario 2 deeply impacts the current topology of the ATC systems. ATFM is also impacted owing to the bundling of en-route ATC and ATFM in a single system, at least for the FM component.

Without being a true "green field" system, the centralised FM needs a specific design that diverges from the ATSU-bound FDPS design of the past and current FDP procurement programmes. The approach is more similar to what is needed for high-availability centralised back-end systems, assuming that proxy servers are implemented in ATSU sites, if needed[13].

Once the new FM is available, the transition plan would start with the stepwise transfer of upper airspace to one multi-FIR UAC centre, as done historically with the Maastricht UAC Centre and now with the Vienna Centre.

The lower en-route airspace would progressively be transferred either to enlarged TMA centres, that use their own FM's, or to the common en-route centre, depending on their intrinsic complexity or other, non-technical, issues.

2.2.7.3. Scenario 3

Scenario 3 is close to scenario 1 except that:

- The data fusion process is located in a server node instead of being left to FD users,

[13] Proxy servers provide a local data caching function that eliminates WAN latency, but requires a cache consistency protocol over the WAN. However, this protocol can be handled at the middleware level, unlike current FD consistency management, which is handled by application level protocols. In addition, proxy servers can implement local data acquisition/distribution rules, adapted to the local procedures, while conforming to a standard interface with the central FM.

- The FD warehouse mostly handles the interoperability protocol between FM's. A few central nodes providing fallback solutions implement the FD warehouse function. In any case, FD beyond one FM's AoR are provided by the FD warehouse[14].

The transition plan could be as follows:

- The services provided by the FD warehouse, for supporting the operational viewpoints of each actor, are specified: ATC, ATFM, Airport, AOC's.
- The FD warehouse is developed and deployed.
- Concurrently, FD users develop client applications to interface with the FD warehouse.
- When ready, FD users connect to the FD warehouse.

The control of IOP protocol between FM's is placed under the responsibility of the FD warehouse that acts like a message broker.

It is worth noting that operational protocols like the OLDI/SYSCO co-ordination protocols are not handled by the data warehouse, but continue to be handled by matching CWP's, as is the case today. In other words, the current OLDI protocol is a recognised way to provide updated FD to adjacent ATSUs, in addition to the co-ordination and transfer actions. When a FD warehouse is available, the co-ordination and transfer operations are kept, but the flight data are retrieved from the data warehouse, instead of being read from the messages.

2.3. Identification of relevant criteria

As expressed in chapter 2, from the technical point of view, one mitigation to current FDP limitations in the ECAC area consists in improving the FDPS interoperability. The logical architecture has highlighted the FM as the cornerstone of interoperability. To improve interoperability between FM's inside the ATM domain (ATFM and ATC), three approaches have been considered:

- To specify standards for FM interfaces, encompassing both the interfaces with connected FD users and the interfaces between FMs:
  - the first interfaces enable clients to adhere to a standard for FM connection, and thus replaceability of components like MTCD can be envisaged[15].
  - the latter interfaces provide the FM interoperability.
- To reduce the source of diversity, by reducing the number of implemented FM's. This is mainly a centralisation action, that makes similar systems share a common FM. Owing to the fact that large TMA's have fairly specific needs and local procedures, the most centralised case consists in setting one FM for en-route ATC and ATFM in the ECAC region.
- To specialise systems in the overall architecture, so as to have:
  - FM's for supporting operational control in ATC and operational flow control in ATFM
  - FD warehouses, providing ECAC-wide FD to interested users

Table 2.1 below presents the criteria that have been retained. In the second column, each cell takes "The alternative" as a prefix. In the third column, each cell takes "In this alternative" as a prefix.

#	Criterion. The alternative…	Description / comment / example. In this alternative…
Operational		
O1	Provides ECAC-wide consistent FD and eases the introduction of foreseen new concepts requiring improved consistency	A set of flight data (script + trajectory) is generated by one system (at least) for the benefit of FD users (they do not have to perform data fusion themselves). Users include AOC's and military units. Data are consistent between ATFM, ATC, AOC, Airports.

[14] As indicated before, here, FD "beyond AoA" concerns flights that never enter the AoA. For flights that fly partially in the AoA, the local FM has the capability to compute the FD beyond its AoA.
[15] Interfaces with connected FD users are demonstrated by AVENUE API's for instance.

#	Criterion. The alternative…	Description / comment / example. In this alternative…
O2	Eases functional evolution and new tools	New functions are more easily implemented in the architecture than today (e.g. owing to standard interfaces[16]).
O3	Preserves local specificity	Local control procedures are not impaired, if they have to continue existing.
O4	Fosters harmonised operational procedures	Harmonisation of ATC procedures is easier than today.
O5	Enables sharing FM and EM	Several ATSU's, for instance, can share a single FM and a single EM. In practice, this solves interoperability issues for these ATSUs.
O6	Satisfies safety objectives	The safety level is not degraded, for instance by introducing new failure conditions.
O7	Satisfies security objectives	No security threat is introduced.
O8	Satisfies efficiency objectives	The expected traffic increase is handled while providing better operational performance indices (e.g. delay reduction).
Technical		
T1	Is technically feasible	Mature technology is available for the target system.
T2	Satisfies performance requirements	Performance indices, like response time and throughput, and capacity objectives are satisfied.
T3	Eases the transition from legacy systems	For instance, integration has a limited impact on the existing systems. No heavy reengineering is needed.
T4	Eases the definition of interface (or component) standards	Standards for interoperability are easy to define for the target system (e.g. owing to a loose coupling scheme).
T5	Fosters dependability	The required availability (availability, max down time) does not need expensive technical solutions.
T6	Fosters maintainability	Maintainability is better than today.
Costs		
C1	Limits specification costs	For instance, interface specifications are needed, with required performance levels, but no system reengineering is specified for some FDPS. New functions are easier to specify: the operations and systems are harmonised among units.
C2	Limits development costs	For instance, each FDP system has to implement a enhanced IOP protocol with peer FDPs, but no new system has to be developed for this purpose. New functions are easier to develop: there are fewer target host or connected systems.
C3	Limits integration costs	For instance, the integration does not need temporary stub systems for providing a stepwise integration of systems. New functions are integrated through standard interfaces.
C4	Limits operation costs	The additional functions do not need significant extra personnel nor computing power nor network bandwidth.
C5	Limits maintenance costs	There are fewer different systems to maintain.
Miscellaneous		
M1	Fosters consensus reaching among stakeholders	Stakeholders are not significantly impacted and there is no conflicting issue. Common requirements are more easily defined (e. g. local specificity is out of the common systems).

[16] Monolithic legacy FDP system do not provide "internal interfaces" that would isolate fine grained processes, like TP, sector list computation, FPM and other. The experience shows that new functions have either to use the existing external interfaces, or these interfaces must evolve to support the new functions, entailing a larger impact on the system. In some case, processes are duplicated to minimise the impact on the FDPS. Potential internal interfaces are exemplified by the AVENUE FDP API's.

#	Criterion. The alternative…	Description / comment / example. In this alternative…
M2	Enables systems suppliers competition	Open competition for FDP, FM or FM sub-components is possible at various levels, owing to published standards.
M3	Respects sovereignty rights	Each state can revert to autonomous operation.
M4	Enables FM outsourcing	The FM can be operated outside the ATSU. For instance, by delegation to a regional or central FM, or even to a facility management company.

Table 2.1: Evaluation criteria

2.4. Assessment of the alternatives

Table 2.2 below gives the overall assessment of the alternatives, using an ordinal scale with symbols +, 0, -, except in some cases where specific values are used:

- One or several "+" denote that the alternative enforces the criterion.
- "0" denotes independence, neutrality or marginal correlation between the alternative and the criterion
- One or several "-" denote that the alternative contradicts the criterion.

#	Criterion	Alternative 1	Alternative 2	Alternative 3	Comments
O1	Provides ECAC-wide consistent FD and eases the introduction of foreseen new concepts requiring improved consistency	-	+ if TMA's have separate FM's ++ if TMA's are covered by the central FM	++	In alternative 1, an FM holds data of an AoI, applying IOP protocols with adjacent FM's to get information in the border area (difference from AoI to AoA). For a given flight, there exist as many FD sets as traversed AoA's, plus the ATFM data set (that can be distributed as the "point profile" in ETFMS Phase 2). In alternative 2, there is one FM for en-route and ATFM and one FM per major TMA. The IOP protocol between ACC and APP/TWR allows the construction of one single data set for a flight by the central FM. However, departure and arrival TMAs own another FD set for the same flight. In alternative 3. There is one node (the central data warehouse in the central option or enhanced FM's in the distributed option) that aggregates the FD from all traversed AoA's for each flight and generates a single consistent data set. Consequently, alternative 2 provides ECAC-wide FD that are consistent with TMA data modulo the interoperability protocol. However, if the central FM is able to cover TMA's as well, alternative 2 could upgrade to a consistent FD without relying on FM interoperability mechanisms. Alternative 3 provides ECAC-wide FD.
O2	Eases functional evolution and new tools	+ for local functions or tools - for common functions or tools	+	+	There is a necessary trade-off: - A customised local FM is considered easier to upgrade from the local viewpoint (e.g. ATSP), as long as local functions or tools are considered. On the contrary, a regional FM is more difficult to change (common stream of change requests, conflicting requests, arbitration through user group, etc) b) For common functions or tools, it is the contrary. One adaptation has to be made to connect to each local FM.
O3	Preserves local specificity	++	-	+	The intricate architecture of current systems shows that there are numerous dependencies between systems concepts and operational procedures. One well-known issue is the adaptation data (or preparation data), whereby operational procedures are "buried" into data files that govern data processing in the FDP, without explicit traceability. Harmonising the data processing through a common FM for instance, has an impact beyond the FM itself. Therefore alternatives 1 and 3, which preserve local FM to some extent, enforce the preservation of local specificity. In alternative 2, there is a need for adapting the local FD users to keep local specificity with a common FM.

#	Criterion	Alternative 1	Alternative 2	Alternative 3	Comments
O4	Fosters harmonised operational procedures	-	+	-	This criterion is antagonistic with the previous one. Local specificity for systems is dictated by local operational specificity. Therefore, it is more difficult to make all different systems move towards a common operational reference than a single new system. It is likely that improved inter-ATSU interoperability in alternative 1 and contribution to a common data set in alternative 3 will impose stronger quality of service constraints to exchanged data than observed today. Conversely this will reduce the degree of freedom for local procedures definitions. However, at this stage, it is difficult to rank alternative 1 and 3, according to their respective impact on harmonised operational procedures.
O5	Enables sharing FM and EM	0 Local decision to share systems	++ Done by design	0 Local decision to share systems	In alternatives 1 and 3, the decision can be made by several ATSP's, to share a FM and the related EM.
O6	Satisfies safety objectives	+ failure confined to one ATSUs intra- or inter-ATSU backup protocol needed	- failure may impact the region (unless prevented by specifically redundant physical implementation and distribution)	+ failure confined to an ATSUs	Unlike RDPS services, no FM service is safety critical (for instance, see the recent FHA study performed for the eFDP project). On the other hand, safety is rather impaired by excessive FM down time, that makes FD out of date and unusable. Consequently, the availability property of FM is of prime importance, with special emphasis on down time. In alternatives 1 and 3, there exist one FM per ATSU or per small cluster of ATSU's. This is deemed a built-in redundancy for providing fallback services from one FM to the other. However, up to now, each FDPS has its own fault tolerant architecture (for instance active or stand-by redundancy), and there is no fallback procedure between ATSU's whereby all FD users would disconnect from the failed FM and connect to the remote back-up FM. Anyway, alternatives 1 and 3 are deemed better for safety, since, whatever the back-up solution, the failure does not propagate directly beyond the AoR, but generates at most a capacity reduction in the AoR. In the case of alternative 2, the failure of the central FM leads to a capacity reduction in the whole region. Therefore, the availability and down time requirements of this FM are likely to be more stringent than those of local FM's.
O7	Satisfies security objectives	+ Intrusion confined to one ATSU	- Intrusion not confined. Larger potential impact	+ Intrusion confined to one ATSU	The same discussion as before can take place for security threats. At first glance, hacking a central system gives more noxious or destructive power than hacking a local system.

#	Criterion	Alternative 1	Alternative 2	Alternative 3	Comments
O8	Satisfies efficiency objectives	- Cross-border functions are limited by AoI's	++ No cross-border limitation	+ Asymmetric access to AoI FD and ECAC-wide FD	Efficiency is taken in the ATM operations sense. Comments to O1 are applicable here.
T1	Is technically feasible	++	+	+	For alternative 1, experience shows that bilateral or multilateral agreements allow the implementation of IOP protocols (ASTERIX, OLDI). OLDI protocols are quite simple protocols that support distributed management. Potentially improved IOP protocols based on messages can be developed using message brokers (discussed in the technical annex) if the routing logic becomes too cumbersome. Alternatives 2 and 3 introduce new systems that need new designs, thus introducing some technical risks. However, there exist mature technology to support large central and mission-critical back-end systems, like banking systems, that are applicable to a central FM.
T2	Satisfies performance requirements	++	++	+	Alternative 1 is based on local FM and provides good response time. Alternative 2 is based on a central FM and thus requires probably local cache servers, for alleviating WAN time latency. Alternative 3 is mixed. For local FM, the situation is like alternative 1. For ECAC-wide FD, there is a latency due to data extraction and fusion by the data warehouse. This means that the performance is not homogeneous depending on the source of FD.
T3	Eases the transition from legacy systems	++	-	+	Alternative 1 and 3 preserve the local systems except when ATSP's choose to share a new system. Alternative 3 adds a new system, which means new development and new interfaces for the legacy systems. Alternative 2 supposes that legacy systems are phased out in ACC's and in the CFMU.

#	Criterion	Alternative 1	Alternative 2	Alternative 3	Comments
T4	Eases the definition of interface (or component) standards	++	-	+	Alternative 1 needs inter-FM interface standards (making up the IOP protocol) for ATC-ATC and ATC-ATFM synchronisation. These interfaces are established between ATSU-level FM's and are based on message brokering with enhanced message definitions and routing rules. The impact on legacy systems is minimum. Each existing FDP system must provide an adapter to connect to the brokering infrastructure. Alternative 2 needs standards for en-route TMA interfaces and for FM-ATC tools exchange, the latter being more difficult to achieve, since: a) the specificity of ATSPs is mostly located at this level, b) there is more detailed interaction to manage (fine grained interface). In practice, this means that all ATSU's that share the central FM must connect all the local components through a standard component interface. To ease transition, it is likely that legacy FDP system are kept for playing the role of both a local FM proxy and an adapter, thus weakening the advantage of a centralised FM. Alternative 3 needs a new set of standards for inter-FM interoperability, but the standard level is close to alternative 1. This is deemed feasible, even if less straightforward than alternative 1.
T5	Fosters dependability	++	- Central FM is a single point of failure	+ FD warehouse failure does not impair FM operation (loss of ECAC wide data)	See comments for O7.
T6	Fosters maintainability	+ for local maintenance - for interface implementation (harmonisation of development plans across ANSP's)	- Merging of many sources of requests for change	+ Local FMs are kept	See comments for O2.
C1	Limits specification costs	+ from the local point of view - from the ECAC point of view	- + from the ECAC point of view	0 from the local point of view + from the ECAC point of view	In alternative 1, specifications are based on local requirements, can be checked locally with a relatively light-weight management process. However, when cumulating separate specification efforts of local programmes, it is likely that redundant work has been done, under different forms. In alternative 2, this is the contrary. Local participants spend time checking common specifications, with potentially tedious and budget-consuming management procedures, but the overall budget may stay below the sum of separate programmes. In alternative 3, some extra work is asked of local participants to determine the interface to the FD warehouse whereas the FD warehouse is specified by a separate body. This could be somewhat similar to what is currently done for the European AIS Database (EAD).

#	Criterion	Alternative 1	Alternative 2	Alternative 3	Comments
C2	Limits development costs	-	++	+	Based on the comments to C1, assuming that the duplication of effort between separate programmes over-weights the economy of scale provided by a central FM or a common additional FD warehouse.
C3	Limits integration costs	+ from the local point of view - from the ECAC point of view	-	- + from the ECAC point of view	Similar to comments for C1 and C2.
C4	Limits operation costs	0	-	-	Operation costs cover the recurring costs of the infrastructure (e.g. energy, communications) and include costs with operational/supervisory staff. They are closely related to the number of sites. Fewer sites lead to scale economy in operational facilities and logistic support systems. Alternative 1 requires no change or only minor changes to the infrastructure (sites, staffing). In alternative 2, a new system is created, that generates additional costs. Some cost savings are expected from decommissioning many, if not all, existing FM's. However, an FM is only one component in an ATSU architecture and the net effect on the operational cost of a given facility is probably negligible. Alternative 3 also adds a new system that generates additional costs, without requiring significant changes to the existing facilities. Consequently, operational cost savings are not provided by the alternatives. Instead, they would be provided by an overall ATM facility planning, for instance by merging some small size control centres into larger ones.
C5	Limits maintenance costs	0	++	+	Same comments as for C2.
M1	Fosters consensus reaching among stakeholders	++ Close to current situation	-- Drastic change	0 Adds a new element and changes IOP principles	See comments for M2.

#	Criterion	Alternative 1	Alternative 2	Alternative 3	Comments
M2	Enables systems suppliers competition	+	--	+ for distributed option - for central option	Alternative 1 is clearly in favour of the three large suppliers that have already captured a part of the European market. Some small suppliers can get niche markets for providing components that fit the prime contractors' product line. Until now, states industrial policies have raised barriers against the open competition in the ATM market. True suppliers competition will only occur if those policies are changed. Alternative 2 is likely to disturb the current ATM business by giving a significant advantage to the contractor that implements the central FM. (Unless the overall system is built in co-operation by them all!) Alternative 3 is more neutral, since local FM's are kept. In the central option, the central FD data warehouse is a new node that is probably a unique system like EAD or CFMU systems, whereas in the distributed option, the local FM enhancement will provide opportunities for several suppliers.
M3	Respects sovereignty rights	++	-- FM for en-route control operated by a central body	+	From the ATSP viewpoint, alternative 1 enables full control of pairwise relationships with adjacent ATSP's. For instance, it is possible to selectively keep full interoperability with one given ATSP while suspending it with another ATSP, or to close the national airspace to international traffic, while continuing domestic operations. Alternative 3 restricts this capability a bit since interoperability is handled by a node shared with other ATSP's, but domestic operations can run in the closed national airspace with the local FM. Alternative 2 almost forbids autonomous domestic operations.
M4	Enables FM outsourcing	0	++	0	FM outsourcing means that an ATSU uses a FM operated by an external body: another ATSP or a specialised body, public or private (e.g. like the EAD consortium). Alternative 1 and 3 are neutral. In both cases, the ATSP is free to determine the FM service supplier. In practice, the tight integration of FM into FDP and possibly other systems in current legacy systems precludes outsourcing of FM alone. Alternative 2 incorporates FM outsourcing by design. All en-route control centres (at least) will be connected to the central FM, possibly through local proxy servers.

Table 2.2: Assessment of the alternatives

2.5. Stakeholders preferences

A questionnaire has been submitted to a first panel of stakeholders during the fourth quarter of 2001. The first part of the questionnaire was devoted to the presentation of the three alternatives and to questions about the preferences of the stakeholders. The list of questions is closely related to the list of criteria given in section 2.3. Small differences stem from the fact that the questionnaire has been released before the interviews of stakeholders started.

A complementary panel of stakeholders has answered the questionnaire after the January 9th, 2002 workshop, providing a more comprehensive set of European ATSP's viewpoints.

We do not intend to present a detailed analysis of stakeholders' preference. Only the salient aspects of the answers will be indicated below with our comments.

2.5.1. Objections to the approach

A few stakeholders have questioned the approach adopted for the institutional study. They feel that system architectures are not relevant for the institutional study, which should focus on the role and responsibilities of stakeholders, and the legal framework of service provision. System architecture aspects are already addressed by other separate studies like the EATMP overall architecture study or the Consistent Flight Data Programme managed by Eurocontrol.

This objection would make sense if the architecture alternatives submitted to stakeholders were pre-empting the results of the above mentioned studies. This is obviously not the case. The institutional study simply needs a system architecture background to root the discussion on matter like system or service provision outsourcing and standardisation.

Unfortunately, none of the Eurocontrol studies was able to provide the required material at the time of writing. On the one hand, EATMP Phase 2 is not launched yet, and only the logical architecture is broadly defined so far. On the other hand, the CFD Programme is currently setting its own priorities and will lead to several studies to be launched soon.

2.5.2. Operational needs

Most ATSP's have stressed the fact the operational needs are under their responsibility and that local specificity must be addressed by any new overall architecture. This is often stated as a major objection against a centralised solution for FD processing and distribution. However, this is expressed in the context of the current monolithic FDP systems that integrate generic core processing and customised user-oriented processing. The capability to separate the FM part of FDP from the connected components would weaken this statement.

Obviously, the legacy systems are deemed difficult to re-engineer in such a direction. Their internal architecture is very intricate and in some cases, design aspects are hidden in adaptation data, tailored for a specific system (see annex on technical architecture).

Besides the need for local customisation, there is no clear consensus on the operational needs:

- It has been highlighted that ECAC-wide consistent FD are not required by ATC. ATC needs a larger geographical scope (or look-ahead time horizon) than today, but still addresses medium term planning and short-term executive control.
- ATFM is strongly interested in ECAC-wide FD, for accurate planning of the traffic in the congested airspace.
- AOC's are interested in accurate estimates of significant events pertaining to the flight they operate, so as to monitor the operations and take decisions regarding potential disturbances. They do not need a precise knowledge of the 4D trajectory of all flights at all times. The pilot is in charge of delivering on the efficiency of the flight.
- Airport airside management is closely related to TWR ATC and AOC operations.

Consequently, there is no single ECAC-wide view of the traffic, but several overlapping views of the traffic. All these views must be consistent. In other words, FD consistency does not mean that the granularity of FD is the same for all stakeholders. This only implies that replicated data must be consistent in the appropriate sense. For instance, a flight event of interest (e.g. landing) for several stakeholders must be known and identical for these stakeholders.

2.5.3. Preferred architecture

Not surprisingly, the high-level and qualitative characterisation of alternatives allows different stakeholders to express antagonistic judgements on the same solution for a given criterion. In fact, each alternative promotes a general architecture scheme that fits –or not– the stakeholder’s general orientation, and to some extent, implications of an alternative on institutional aspects dictate the judgement on the architecture. Moreover, it is widely recognised that all three architectures are technically feasible, independently of various advantages and drawbacks. Therefore, technical aspects are second order to other aspects like the capability to preserve local specificity, or the minimisation of transition impact on legacy systems, especially when the so-called legacy systems are in fact quite recent systems, or even planned developments.

Bearing that in mind, most ATSP’s that currently provide area and approach/tower control are in favour of alternative 1, which preserves the current organisation whereby each ATSU operates its own FDPS. They prefer a peer-to-peer co-operation of ATSU-level FM’s to a hub-and-spoke co-operation. They also endorse a co-ordinated standardisation effort that would solve the data inconsistency problems and cater for the introduction of new functions and related tools. Some of them express doubts about the feasibility of providing separate FM services: they feel that the generic structure of an ATSU incorporates an FM.

Some individuals foresee a new ATC organisation whereby en-route control would progressively be delegated to a single en-route centre, owing to progress in aircraft autonomy and reductions of ATC involvement in the en-route airspace. On the contrary, the focus will be put on TMA airspace, with more advanced ATC functions than those available today. Obviously, this longer-term view contradicts the view of the majority.

One stakeholder advocates the move towards alternative 2, which solves most if not all FD consistency problems at once, and introduces potential economy of scale in procurement, operation and maintenance.

In general ATSP’s challenge this view for several reasons:

- In the past, collaborative projects that involved a large number of partners have failed because convergence is hardly, if ever, reached on requirements, transition policy, etc. This almost precludes a centralised solution.
- Assuming that a central system exists, evolutions will suffer from the same syndrome. This would introduce a lack of flexibility for ATSP’s and potentially impair fairness with respect to change requests formulated by smaller ATSP’s.
- Security, dependability and performance levels of a central solution are deemed weaker than those provided by a distributed solution. To reach the required QoS figures would require very costly solutions.
- In case of unavailability of the system (e.g. period of crisis) or in case of destruction, a state may be prevented to exercise its sovereignty rights due to its dependence to this essential function.

Industry representatives are generally in favour of alternative 1. They also advocate strong standard setting efforts for allowing a better inter-ATSU interoperability.

It should be noted that one ATSP found that interoperability protocols were missing between the local ATSP FM’s, AOC FM and Airport FM, which are deemed essential for Gate-to-gate operations, and more generally that scenarios do not cover properly airport and military viewpoints.

The questionnaire was probably not clear enough about the scope of the presented scenarios[17], and thus, it was not evident that airports operations were left out on purpose. However, it is obvious that any future work should pay attention to the interface between:

- APP/TWR ATC, that handles arrival, departure and surface movements,
- AOC's that makes decision about ground operations pertaining to their flights and
- resource management by the airport authorities,

so as to enable airports to build and monitor accurate schedules.

There is indeed a special stream of work to undertake in order to integrate the viewpoint of airport operators. In the interoperability study, for the sake of simplicity, the management of airport resources is assumed to be handled by a local airport system, which is synchronised with ATC and AOC's by notification of a limited number of flight events that are significant for the airport schedule.

The airport management system therefore is considered to be one of the non-ATM flight data users. When airport operations generate constraints on flights, these constraints are integrated into the flight script in the appropriate form by the TWR ATC. For instance, the unavailability of a ramp may impose temporary parking before reaching the apron, thus changing the ground movement of he plane, or the unavailability of a boarding room or another resource may delay passenger boarding and lead to miss the departure slot, etc.

2.5.4. Future vision

Most ATS providers are keen to follow a smooth transition from the current systems to a more integrated or harmonised future system. However, there is no established consensus on the future system itself.

The idea of an upper airspace controlled by a single ATSU with free flight possibilities does not gain a wide acceptance among ATSP's.

However, there is a large consensus among stakeholders to design the future ATSU's taking the operational needs as the main input parameter and not for national convenience. This entails a reduction of the current number of ATSU's, especially for the small FIR's and UIR's, that match the borders of small countries.

[17] The scope of the alternatives is clearly defined in the present document in section 3.2.1.

2.6. Convergence Architecture

Figure 21 illustrates the overall architecture that could result from both the previous assessment and the feedback from stakeholder's interviews.

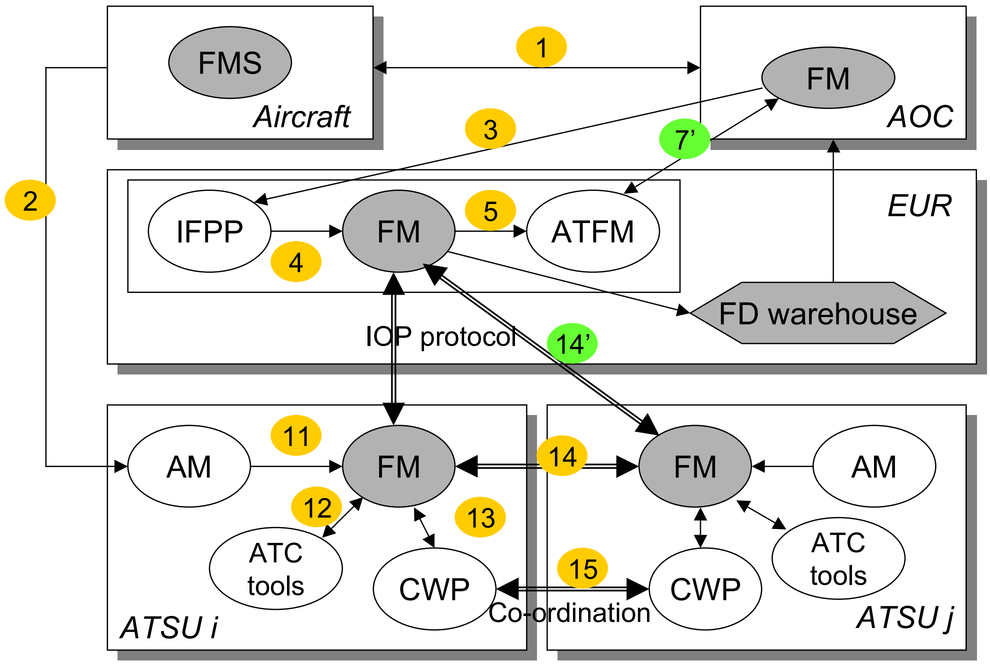


Figure 2.9: Convergence architecture

The flows in the architecture are listed in the table below

#	Between	And	Flow
1	AOC/FM	Aircraft/FM	FPL/ In-flight report
2	Aircraft/FMS	ATSU/AM	Aircraft down-linked parameters
3	AOC/FM	IFPP	FPL (ICAO definition)
4	IFPP	Central FM	Validated FPL
5	Central FM	ATFM	FD/ 4D constraints on airspace resources
7'	ATFM	AOC	Departure slot & point profile + elements of improved CDM protocol
11	ATSU/AM	ATSU/FM	ADD (Aircraft Derived Data)
12	ATSU/FM	ATSU/ATC tools	FD / FD update request
13	ATSU/FM	ATSU/CWP	FD / FD update request
14	ATSU i/FM	ATSU j/FM	FD in ACI, FD update events
14'	Central FM	ATSU/FM	FD in AoR, FD update events, slots + elements of improved CDM protocol
15	ATSU i/CWP	ATSU j/CWP	Co-ordination events

This architecture solves two issues raised by the alternatives that rely on a central node:

- The central FM (or a few regional FM's) in scenario 2 are potential single points of failure.
- The central FD warehouse, playing the role of an "interoperability box" in scenario 3 is also deemed a potential single point of failure by ATS providers.

The proposed architecture mixes the network of ATC FM's with an additional central node that makes the fusion of replicated parts of flight data, for the benefit of non-ATC and non-ATFM users.

ATC FM's are located in ATSU's. This does not preclude the possibility of placing a cluster of ATSU's under the authority of one shared FM. In any case, there is a tendency towards a reduction in the number of ACC's.

Some ATSP's will continue to provide FD to TMA's (APP, TWR control) from an ACC-based FM, as done today.

Other ATSP's might move to TMA-centred control with a FM per TMA or cluster of TMA's, with an AoR including entry/exit points managed by the integrated AMAN/DMAN system. A cluster of TMA's would possibly control traffic over high-density inter-TMA direct routes, leaving the rest of en-route control to a regional ATSP with its own FM.

In any case, ATSU FM's inter-operate through an advanced IOP protocol that we will call Unified Inter-FM Protocol (UIFP), so as to ensure efficient flight transition between AoR's and fine-grained cross-border medium-term planning. An example of an advanced IOP service is the negotiation of 4D constraints on TMA entry points.

There is only one ATFM FM. It is located in the CFMU facilities.

The IFPP function is an evolution of the current function of IFPS. IFPP provides the single entry point for flight plan filing to airspace users. However, IFPP does not connect directly to ATC systems. It pre-processes (validates) the FPL and transfers it to the ATFM FM. The IOP protocol between ATFM FM and local FM handles the current IFPL distribution. It allows the sharing of a more accurate view of the flights. Updates to flight plans made by local FM's are synchronised with the ATFM FM as done with other FM's (this replaces the current AFP message). However, the IOP protocol between ATFM FM and ATSU FM could be a limited subset of the UIFM.

The ATFM function is an evolution of TACT, including CASA. It is responsible for tactical allocation of departure slots, minimising ground delay as much as possible. The IOP protocol between the ATFM FM and local FM's provides ATFM with accurate flight scripts for estimating airspace entry/exit times and deriving load indicators. Improvements to the current TACT/CASA slot allocation algorithms would certainly benefit from a more accurate view of flight scripts.

All previously mentioned FM's use their own trajectory prediction over their AoA. The AoA of the ATFM FM is the whole ECAC area. The FD warehouse implements a read-only service for non-ATM users. It retrieves FD from the ATFM FM and may apply distribution restrictions when appropriate. It provides neither ATFM nor ATC operational service. In particular, unlike the data warehouse of scenario 3, the FD warehouse no longer controls the IOP protocol between FM's.

Since the FD warehouse is a central node, an option could be that the FD warehouse is integrated into the ATFM node, instead of having two separate systems. There could be one operational Flight Database for the ATFM FM and a read-only replicated database for data distribution to non-ATM users.

3. ORGANISATIONAL ISSUES OF CO-OPERATION

3.1. Statement of work

3.1.1. Objectives

The objectives of this work package are twofold:

- to explore the opinion of the stakeholders concerning the need for institutional improvements. A questionnaire have been used with a view to getting their feeling about :
  - the potential insufficiencies in existing regulation and organisation,
  - the types of organisation and regulation related to FDP systems desired for the future (in the form of improvements or radical changes to the current situation),
  - the advantages expected from these organisational / institutional changes.
- to survey a sample of projects in the ATM-CNS field which have been conducted in a European collaborative context, in order to analyse their success or failure in respect of the different problem areas that have been identified. The projects, selected for their exemplariness with respect of our scope of interest, are: ARTAS, eFDP and AVENUE.

3.1.2. Approach

The range of opinions has been classified by domains following naturally the structure of the questionnaire.

The survey results have been pictured by a series of bar charts. For the sake of readability, the stakeholders have been grouped in only four categories: ATC Service Providers, Airspace Users, Industry, and “Others”, the latter category gathering the Eurocontrol, CFMU, and EMEU answers.

Some domains have been broken down into more “elementary” issues, to make it clearer the interpretation of results (a mix of different institutional issues is sometimes covered in the questionnaire with one shot). It was in general possible to know the respondent’s opinion about these issues by just cross-checking several of his responses, or by relying on his own comments (free text fields have been filled in by respondents when they wanted to reinforce their arguments).

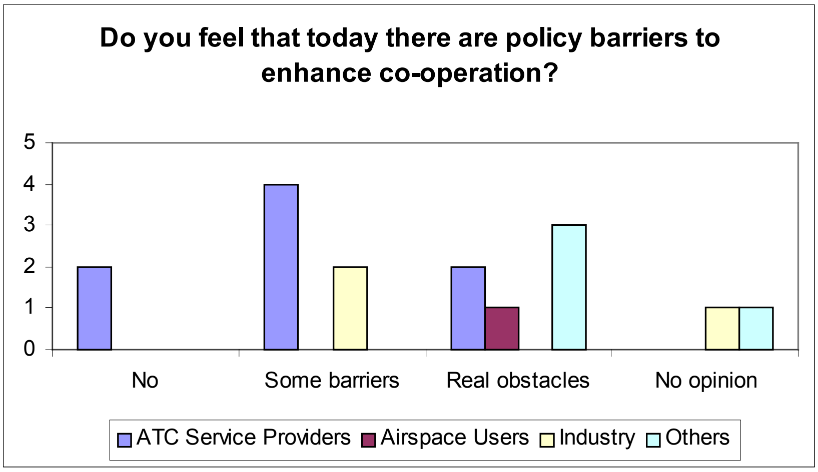
3.2. Results of the survey

3.2.1. Current arrangements and European policy to enhance co-operation

There is a general consensus among respondents to recognise that the current situation is not appropriate to a larger co-operation among actors of ATM. As the need for cross-border co-operation is ever increasing, the institutional and organisational instruments presently available have reached their limit.

This result is reflected in the diagram below, which shows also that the respondents are divided over the seriousness of obstacles, and thus over the possible solutions to remove them.

Most of ATSPs agree that there will be more and more co-operation needed at regional level in planning, procurement, and possibly operation, and they see here a role for the European institutions to foster the process. A few respondents insist on the need for measures to stimulate investment and commercial co-operation at various levels between stakeholders, and advocate new models of funding for regional projects encouraging withdrawal from national to more global paradigms.



The questionnaire suggests a solution in terms of common standards, but the general feeling is that the current obstacles are not so much of a technical nor of an operational nature, but that they are inherited from the past fragmentation of service provision. The outcome of it all is that ATSPs tend to perceive themselves as competitors.

There is a debate about the means:

- some respondents are convinced that a consensus can only be forced by a political decision at European level. They regret the lack of enforcement of common decisions[18], and would see the EC playing a role in the definition and supervision of ATM activities taking account of the global efficiency of the system in a single sky approach.
- others believe that trans-national co-operation can only work on a voluntary basis[19] and between a small number of states, the role of the European Union in the latter scheme being to encourage these initiatives e.g. by proper funding mechanisms

The stakeholders put forward various suggestions in terms of the possible financial incentives to facilitate co-operation and standardisation, including:

- funding dedicated to common definition of requirements and standards,
- funding dedicated to the development of interoperable FDP systems,
- economic regulations: e.g. inclusion, in the charging principles, of mechanisms rewarding system-wide efficiency practices such as the introduction of systems which implement interoperability rules.

3.2.2. Role of stakeholders

The interviewees have brainstormed the possible roles that could/should be assigned to the various stakeholders in the future.

The following “wish list” does not claim to be representative of the general thinking, and does not imply any specific ranking neither. It may reflect the sensitivity of those who wanted to

[18] “There is no commitment by ATS providers and Eurocontrol to implement concepts in a mutually agreed, stepwise way, following a specific calendar.”
[19] One respondent said that “trying to enforce co-operation at EU level will not work better than at Eurocontrol level.”

explain their opinions in their answers, but its great merit is to highlight the points deemed worth raising by respondents.

1. Co-ordination between domains, programmes and institutions is deemed necessary in order to reduce/avoid duplication, contradiction, conflict, overlap and redundancy of actions.
2. There is a request for a clarification of the roles of EC, Eurocontrol and the States in regulation activities[20]. The separation between service provision and regulation is not widely accepted, and some people have doubts about the ability of some states to fulfil their role as regulator (e.g. in the field of ATS provider licensing).
3. Competition between ATS providers is deemed prejudicial to the achievement of global optimum solutions to ATC problems.
4. The possibility that European decisions may adversely affect investment decisions already made (as well as the operational lifecycle of their recent developments) is a matter of concern.
5. There is a request for a clearer definition of stakeholders' roles (EC, Eurocontrol, ATSPs, ANSPs, ASPs, Industry, states[21], ECAC, ATFM, MIL, Aircraft Operator, Airport Operator, EUROCAE, CANSO, FAA, ICAO, etc.) throughout the whole life-cycle of the system, i.e. from definition to operation, which does not leave anybody out.
6. Stakeholders advise caution as soon as the matter is about a modification to current organisations. Today, ATSPs are "all in one" monolithic organisations; the ATS quality is a product that depends on air traffic controllers' performance and the quality of the ATM system service, ancillary services, infrastructure services: this is all managed by a single provider, the ATSP. There are concerns about "the price to pay" for a liberalisation/de-regulation in this area, because a split would create new interfaces[22].
7. The Eurocontrol leadership is widely recognised in the field of global operational concepts and requirements definition.
8. The role of Eurocontrol in the architecture definition is much more challenged. The general thinking is that the definition of system architecture at the level of components is the business of ATS providers and industry, Eurocontrol is merely seen as a facilitator.
9. Industry manufacturers would like to be involved "in the loop" very soon in this definition process[23], and request for proper funding from the EC in this regard.
10. On the contrary, some ATS providers do not think that manufacturers should be pro-active in setting design requirements, arguing that as much competition as possible should be retained in procurements[24].
11. If the EU is given a pro-active role by enforcing the definition of a roadmap for the implementation of interoperability requirements and controlling its enforcement, this should involve that the EC, on the basis of Eurocontrol's recommendation and technical support:
    1) co-ordinate the definition of operational concepts and requirements, functional specifications, including realistic interoperability requirements and facilitate the standardisation of those requirements,
    2) co-ordinate with the ATS providers the definition of a roadmap for implementation (analogous to ECIP),
    3) make sure that those requirements are the baseline of ATS provider's RFT's,
    4) regulate the entry into service of new systems, including conformity assessment procedures applicable to all parties (ATS providers, manufacturers),
    5) verify the efficiency of the system through a performance review commission,

[20] A respondent worried about the possibility that the role of states be reduced to the control of the application of rules defined commonly at a higher level.
[21] Stakeholders are in general not used to make a distinction between the notions of regulator and service provider.
[22] "The regulator has to take decisions based on economy which in turn is based on contracted promises. What would be the consequences in case of degradations in the quality of service, losses of capacity, increased costs, increased unemployment, etc.? The best regulation does not help if the overall organisation does not work."
[23] One industry respondent said that "Technical and industrial feasibility of concept needs to be assessed by Industry."
[24] One stakeholder sees a lot of difficulties in aerospace firms becoming active in the ATM system: "Would they treat their aerospace competitors fairly?"

6) animate a kind of user group to update the requirements (difficulties encountered, improvements…).

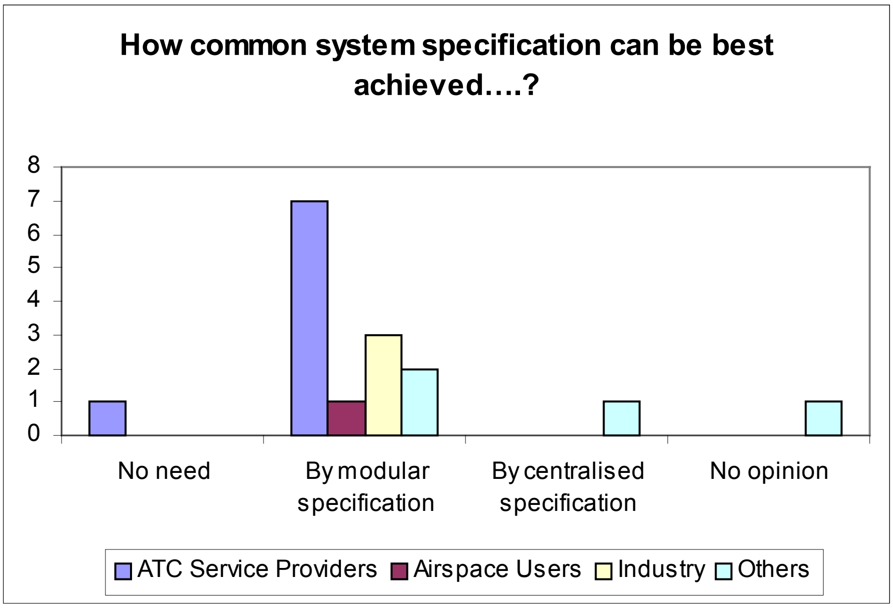
To complete the picture, it is worth recalling some observations taken from the Eurocontrol document “Supplier relations and policy” [C17] (1998) which, amongst other things, discussed the optimal use of industry capability for a cost-efficient development of ATM systems. These findings - resulting from contacts with industry - go beyond the scope of the direct relationship between Eurocontrol and its suppliers:

- Industry is not involved early enough in projects. This may lead to specifications either too complex or too costly to implement. This should ensure a better use of existing capabilities and a reduction of the time-lag between R&D and implementation. However, early involvement of industry (especially manufacturers), if not properly managed, may bias specifications towards existing products and therefore hinder innovation.
- Because Eurocontrol performs different kinds of activities, it is necessary to clarify the role of Eurocontrol regarding the CAAs and Industry. Eurocontrol should define and validate high-level functional specifications (I.e. avoid technical over-specification), and leave development to industry. Industry expects Eurocontrol to impose relevant standards, leaving industry to develop products to those standards (and not promoting *the* preferred solution for achieving compliance with agreed standards).

These comments are still valid today, even it is fair to note that Eurocontrol has since taken actions to improve the situation: information to suppliers, definition of a Industry-based Prototype (IBAP now ERIS) where systems from several suppliers could be interconnected, participation of the stakeholders in the definition and follow-up of the project (ERIS, CFD…), framework contracts.

3.2.3. FDP procurement policy

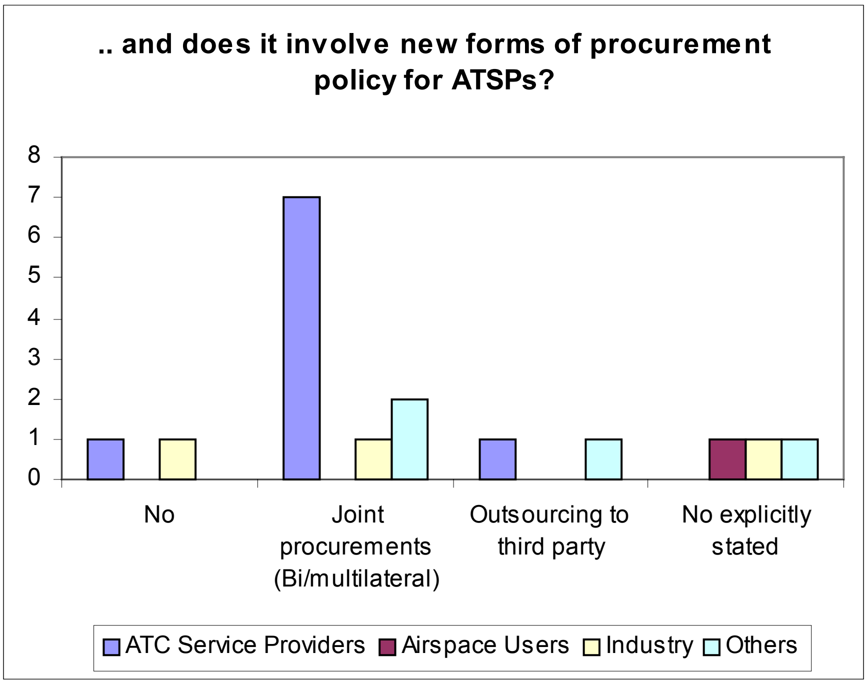
The general feeling is that the specification of FDP systems can no longer be done in isolation, and that states must strive together for developing sets of common specification based on jointly agreed modules:



Some respondents think however that ATSPs without an umbrella may be successful in bilateral but not in multilateral environments, arguing that, today, service providers continue to reinvent the wheel whereas specifications jointly established between Eurocontrol and stakeholders are already available. Some more radical solutions have therefore been suggested to change this situation, like the development directly by industry of a component-based architecture (e.g. under proper funding by the EC) or in the other extreme, of a central FDP system.

However few ATSPs, if any, are confident in the latter alternative; they think that either of these solutions would need a strong political and economic support from the European Union to aim for some viability[25].

The next diagram confirms that almost all ATSPs do consider the possibility of a collaborative approach to specification for future procurements. The position of industry is not so clear-cut, may be because a jointly process is seen as a commercial risk by those who benefit already from a privileged relationship with their usual customer.



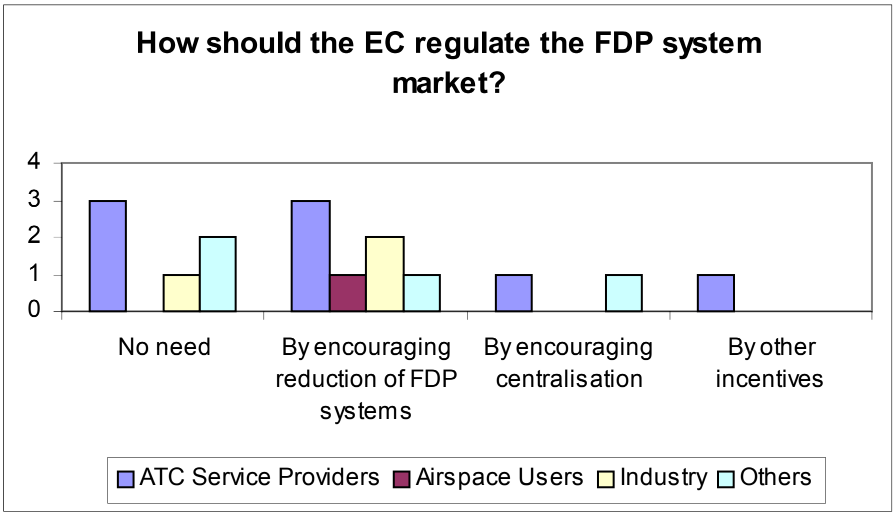
The stakeholders are divided over the need for a regulation of the FDP market. Nevertheless, about 50 % of respondents think that the European Union should encourage a reduction in the number of FDP systems in Europe, but not necessarily through regulatory enforcement[26]. Facts prove it is possible (see bilateral or multilateral initiatives for new FDP's or common ACC like CEAT).

If some believe that there could be a strong case for a single central system if this solution was not so radical in essence, almost all ATSPs are firmly opposed to this option. A major argument is that in case of unavailability of the system (e.g. period of crisis) or in case of destruction, a state may be prevented to exercise its sovereignty rights due to its dependence on this essential function. Another reason often put forward is that centralisation would rule out the FDP market despite the multiple back-up functions and system instances in various

[25] One industry respondent emphasised that all actions aiming to minimise procurement risks have to be encouraged (e.g. concept validation, cost-benefit analysis, standardisation, pre-operational validation)

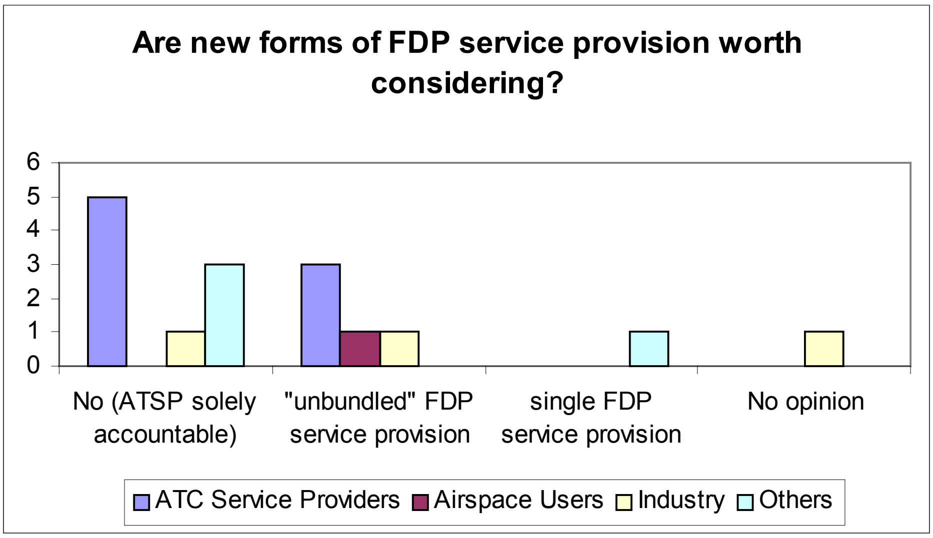
[26] "The reduction of the number of FDP servers to a possibly reduced number of ATSP's should be left to occur through voluntary co-operation and market force rather than through regulatory enforcement. All that needs to be done is to make sure that the technical solutions retained for the future interconnection architecture do not preclude that reduction (and that implies stringent common interoperability and performance standards)."

locations needed in any cases. Some stakeholders added that the number of manufacturers is already small and must not be further reduced.



3.2.4. New forms of FDP service provision

This idea to separate the FDP service from ATSP's core businesses is controversial. From both a technical and operational point of view, the unbundling of the FDP function is not that innovative: e.g. there are today groups of TMAs serviced by remote FDP systems. From an organisational and institutional point of view however, the option to confer the responsibility of FDP service provision to a separate body is unprecedented.



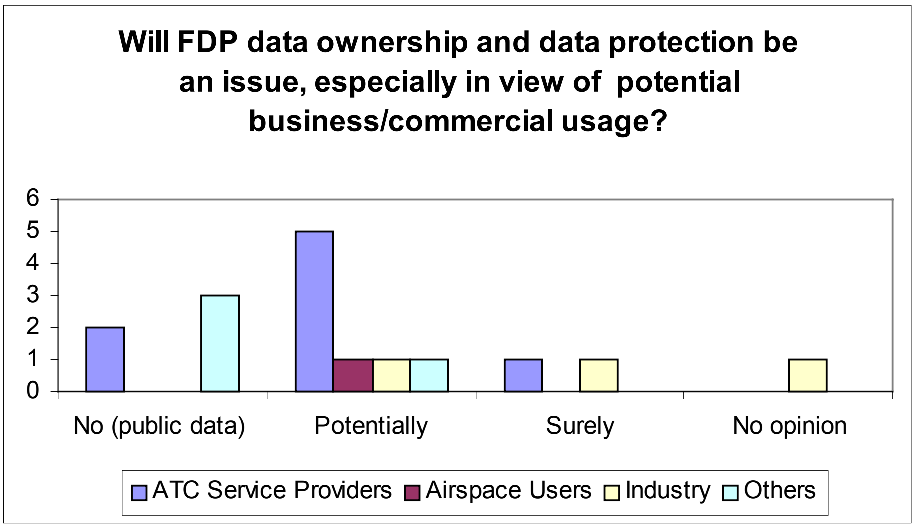
Not surprisingly, this option is contested, sometimes firmly[27]. There may be barriers in national regulations that prevent any form of delegation to a privately organised non-national provider. Some stakeholders disputed also the technical feasibility of this approach[28].

[27] One ATS provider said that he could not allow the procurement and development risk to be managed remotely by an organisational structure over which he would have limited control.

It is worth mentioning however that nearly half the respondents – including some ATSPs – do consider it a possibility, especially to promote competition and as an enabler to the flexibility required in a concept of control by Functional Blocks of Airspace[29].

According to most of these respondents, there are very sensitive points to be sorted out related to contingency, sovereignty (as soon as a regional entity involves servicing several states) and liability issues. Some ATSPs expect "special measures" to be applied "in those times when sovereignty questions become predominant".

3.2.5. Data ownership and data protection



There are two balanced trends in respondents' opinions:

1) those saying that the notion of FDP data ownership is irrelevant, FDP data are public data in essence. But the dissemination of FDP data to any interested party should be limited on the basis of specific safety, security and privacy protection constraints. Partial or total access rights should be granted only to those people and/or organisations that can justify a professional need[30].
2) those who think that ownership of flight data may be held by multiple parties, depending on the application and value added in each context. This involves that the accountability/responsibility for flight data should be established and maintained for integrity purposes. Additional commercial/business value may be derived from the use of flight data beyond its original purpose; this is considered a potential EC wide legal issue.

Whatever the alternative, ATSP respondents emphasised that ATM Service Providers should be granted free access to flight data relating to their Area of Interest, any restriction on data access would represent a direct constraint on their ability to provide a service. The Commission should, by regulation, enforce the free circulation of data in this context.

[28] The main reason is that the FM is as much a server as a client of the different tools (CWP, MTCD, Flight Path monitoring, AMAN/DMAN, etc.) too linked with the other functions to be externalised (reliability and performance issues).

[29] "The introduction of the functional blocks of Airspace will break up the fixed relationship between service providers and their given airspace, owned only by them. This might result in a need (or a chance) for the then new service providers to make use of basic infrastructure in a flexible manner. Then, we can imagine a European FDP "regional" environment in which a number of, e.g. 3 separate systems would be available for common processing of data. The final technical solution will depend on the business plans/decisions of the providers of these services."

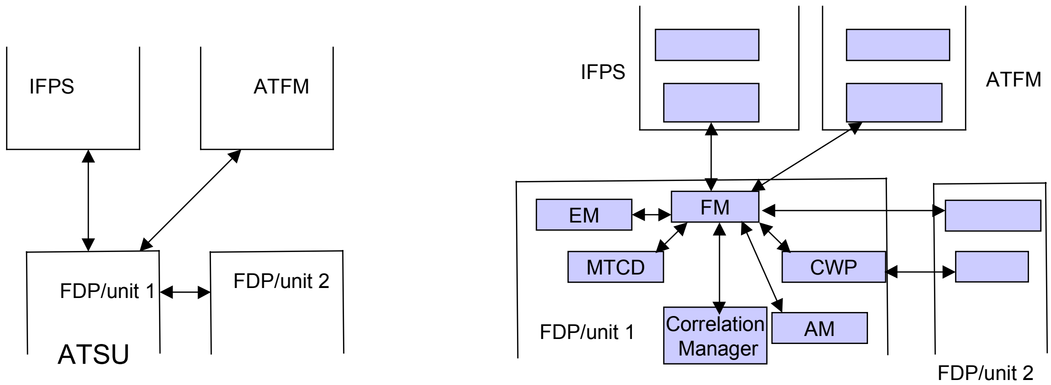
[30] One respondent added that "Introducing a delay to accessibility may be a simple means of preventing misuse in the context of open commercial competition (i.e. real-time access would be possible only for operational user needs".

3.2.6. Level and scope of standardisation

Almost all respondents think that current standards (ICAO SARPs, OLDI), which are limited to specifying common data exchanges and FP formats, are not appropriate to the level of interoperability required by next generation FDP systems.

There is a large consensus to establish and enforce common standards, but there are two attitudes in the debate on the extent to which they should be defined to provide their benefits:

- those who think that interoperability can be enhanced merely through increased data exchanges between systems (e.g. FDP-FDP, ATC-ATFM, ATFM-AOC, ATC-aircraft);
- those who defend a more distributed approach based on a component-based architecture[31].



Between clusters of EOA components

Between EOA components (=> inside ATSU)

Figure 3.1: Two levels of standardisation

The stakeholders put the highest priority on the first option, and consider in general that this level of standardisation should be mandatory. This approach implies in particular a consensus on the definition and roles of systems (including IFPS, CFMU, EAD).

Some ATSPs think that the second option addresses internal ATSU design issues which fall rather to them. The respondents favouring the second approach believe that it gives good prospects of costs reductions in terms of development/ integration/ customisation, but the required standardisation would only be possible on a voluntary basis jointly by industry and ATSP's. They say that the user requirements in terms of operability/ standardisation/ modularity should be integrated from the outset in the definition of a target architecture.

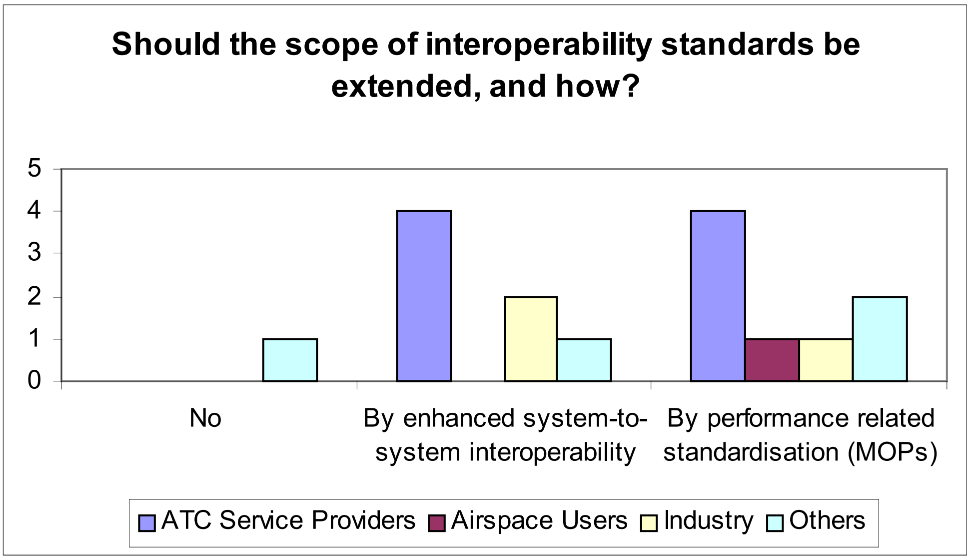
The concern of industry is that standards be defined at the "right level". They advise against a too deep standard definition that would impede the necessary freedom of design and innovation.

The stakeholders have been questioned about their wish to see the scope of current standards extended to the notion of performance.

The most "conservative" say that the ATC functions and systems are very intricate and tightly coupled. In particular, it is difficult to define the performance of a component, or a part of the system, in isolation of the rest.

[31] These two options correspond to the working groups 59 and 61 that have been created in EUROCAE.

However, there is a slight majority of respondents having ticked this possibility because it is more directed at increased openness of the FDP market and competition between industry manufacturers. It is deemed more supportive of a component-based approach and forms of externalisation.



The most common position is that performance standards could help especially for those components of the system that would interact directly with the aircraft systems and for really safety-critical elements, but not necessarily on an overall basis (because of the cost of end-to-end certification).

More generally speaking, a number of stakeholders think that standardisation activities should address a wider scope than today, to encompass the logical architecture of the system, interoperability requirements, the conceptual model of data, interfaces between modules of the system, and the quality of service[32]. Whatever the options, the respondents agree that interoperability standards, should be defined through a large participation of the stakeholders, and they see in general EUROCAE as the right vehicle for this activity[33]. One ATSP respondent suggests that where interoperation is made mandatory, or where states are pushing towards implementations against European Standards, a regional agency (like Eurocontrol) should validate the standard with the proviso that ATSPs have an input to the process.

Some points from [C17] are worth to be highlighted:

- Suppliers want to be more involved in the standardisation process. They believe standards should be directed towards interoperability and achieving harmonised performance levels. In other words, standards should not be too detailed technically.
- Several suppliers say formal standardisation of flight data processing systems will remain necessarily limited, and that alternatives should be explored that might help achieve more easily the objective of harmonised and integrated systems. They mention in particular the validation of new functions and the dissemination of the corresponding results, leading to some de facto standards (e.g. ODID IV).
- Another aspect concerns the process by which conformity of products, or systems, to standards is checked. Industry strongly believes there is a close link between standardisation and validation or

[32] "Standardisation should focus not only on the definition of services (including behaviour and performance of the system) and messages (syntax and semantics of data exchange) but also on the absolutely unambiguous definition of the data."

[33] A few ATSPs fear however that doing so, they may be imposed de facto standards by the most influential stakeholders, and recommend a proactive implication of Eurocontrol.

certification. However, it knows the associated costs can be significant and must be carefully balanced against the expected benefits.

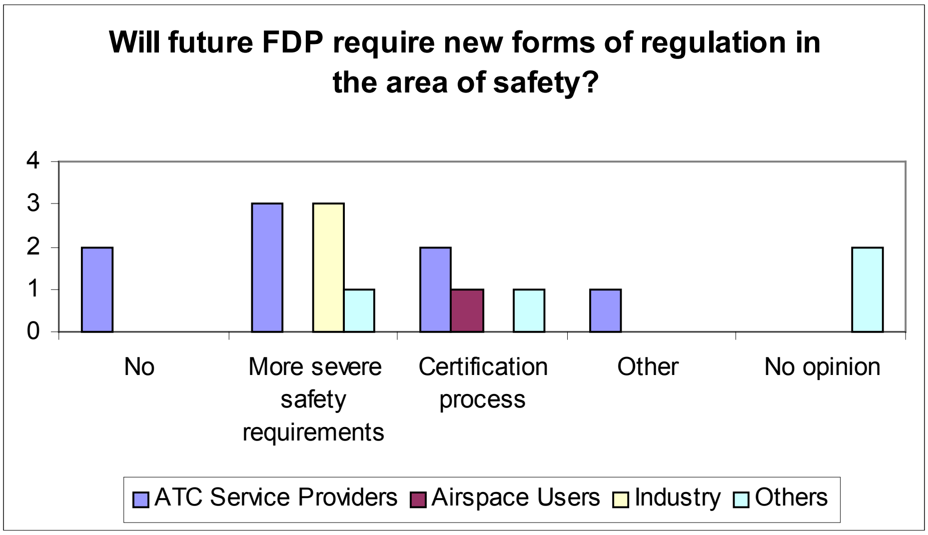
3.2.7. FDP related safety issue and certification

The general trend coming out from the collection of answers is that “something” has to be done in this field. The opinions are however quite diverse about the way forward.

The most “conservative” recognise that the current regulatory framework is a bit weak, but that safety standards currently under development (ESARRs) should suffice.

A number of interviewees think that the first priority should be put on the production of safety requirements, explaining that certification may be considered at a later stage from an air/ground integration perspective (according to them, the FDP system is not so safety-critical to justify a full-fledged certification process). Respondents from industry pointed out that certification rules similar to the processes currently applied to aircraft would considerably impede the flexibility of the system, and its adaptability to technological breakthroughs.

One ATSP would like to see, instead of these proposals, the application of a “common safety framework” across Europe.



3.3. Survey of European collaborative projects

The purpose of this section is to assess some projects led through a European collaboration and to see which lessons can be learnt for future developments.

3.3.1. ARTAS

Reference: Eurocontrol web site and [D16]

3.3.1.1. Description of the project

ARTAS is the concept of a Europe-wide distributed Surveillance Data Processing System that has been developed by Eurocontrol for implementation in the ECAC area. The system concept relies on the implementation of interoperable SDP Units which all co-ordinate to act as one region-wide integrated Surveillance system, ensuring a fully seamless operation. The elements to build such an SDP network are the ARTAS units, or any other SDP system fulfilling well-defined interoperability requirements.

The interface between ARTAS and its ATM User types is of the Client/server type. Each user may, through the appropriate dialogue, define in a dynamic, flexible, and exact way which Track Information Service it expects.

The adjacent ARTAS units are designated to co-ordinate their tracks to build a unique, coherent and continuous Air Situation Picture over the complete area covered by their individual Domains of Interest.

The ARTAS concept relies on two key words of the EATCHIP Program: harmonisation and integration:

- Harmonisation, by common operational and performance requirements definition.
- Integration by the fusion of surveillance systems, erasing geographic borders.

Modularity and interoperability were also key concepts. One hypothesis was that the ATM centres were going to evolve from a monolithic architecture to a component-based architecture where the different blocks could be developed independently. Interoperability was procured by the standardisation of the interfaces.

Taking in account the level of investment which was necessary to define a high level tracker, a common approach had to be made. Radar experts under the umbrella of Eurocontrol defined the common requirements. A call for tenders to develop a pilot system has been done.

ARTAS is now distributed in many ECAC countries, being operational in some of them. No licence fee is charged for ARTAS Application Software when it is made available to air traffic management administration of a ECAC Member State.

Concerning ARTAS Industrial policy, Eurocontrol grants to ATM industry the opportunity to gain access to the ARTAS Application Software, thereby enabling, if so desired, to integrate ARTAS within existing product line and increase ability to compete on the open ATM market. The idea was first to give the opportunity to gain access to the ARTAS source code. It appeared soon that this was unmanageable. Eurocontrol has centralised the maintenance of the system in the Maastricht centre and ARTAS Software is considered now as a black box integrated in the offers of ATM Industry manufacturers.

3.3.1.2. Positive results

The technology of the tracker was about ten years ahead of its main competitors at the time of its development. Since then, it has proved its efficiency and is used now with a lot of different types of radars.

Harmonisation between systems has been a success, the requirements and interfaces definition being widely accepted.

Flexibility and interoperability through both a client/server approach and standardised interfaces have been demonstrated.

The centralised development and maintenance proved to be cost beneficial.

3.3.1.3. Negative results

The States never admitted that the elaboration and compilation of the surveillance picture pertaining to their area of jurisdiction could be partly dependent on another State. As a result, each centre continues to possess its own unit processing the national data to cover its area of interest[34], and the function of tracking continuity between adjacent units has not been implemented.

ATSPs want to be immune to any potential consequence of communication failures, and to any crisis with their neighbours likely to affect the integrity/availability of their surveillance

[34] i.e. even beyond the limits of its sole area of responsibility

picture. The surveillance units have not been, properly speaking, “integrated”[35] whilst ARTAS was supposed to help to “regionalise” the service independently of geographical borders. So we can say that the surveillance enabler to “fully seamless operations” has not been achieved.

The user needs were not completely reflected in the ARTAS concept, the approach has probably been excessively “top down” orientated, and has underestimated the users’ position on safety and sovereignty issues, as well as their resistance to change.

The ATC systems did not evolve to a component-based design contrary to what was foreseen, making it difficult their integration with ARTAS. This was certainly due to the lack of a common willingness to develop things in this direction, and also the absence of an overall management, probably too difficult to organise. Furthermore, ATS providers that had already implemented an up-to-date surveillance system had no need to replace it. The implementation of ARTAS in ECAC centres is therefore a lengthy process.

Other manufacturers deemed the awarding of the development of a pilot system to one manufacturer unfair, and some States resented strongly the discarding of their national supplier. Eurocontrol decided therefore to transfer the ARTAS integration competence to other suppliers and to develop an ARTAS competence within a consultancy firm in charge of the maintenance unit. The major ATC system suppliers have then integrated ARTAS in their offers. Eurocontrol has now modified its strategy with the development of new systems by two suppliers in parallel (POEMS project) leaving the IPRs with the suppliers.

3.3.1.4. Lessons learnt for future European collective development

The notion of “fully seamless operation” suggests a reduction of systems units and centres which goes against the will of ATS providers to retain full control over their systems - mainly for safety and sovereignty reasons - even if this is at higher cost for them.

It has been proven however that it is possible to harmonise the requirements, and to define standard interfaces even for large-scale and complex systems.

The definition of a new system is driven by the user needs, and its acceptability depends on its perceived value added with respect of legacy systems.

The development and maintenance of a unique system replicated as far as necessary is cost efficient, but it may conflict somewhat with the policy to promote competition and competence sharing amongst industry suppliers. The ARTAS experience has shown that manufacturers do not want Eurocontrol to play the decision maker role in the procurement and development of operational systems.

The IPRs have to be clarified from the outset, and the share of IPRs between several participants must be avoided.

3.3.2. EFDP

(eFDP is no longer referenced on Eurocontrol web site)

3.3.2.1. Description of the project

By Mid-90’s, NATS and DNA were both investigating the replacement of their legacy FDPS.

Owing to the collapse of the DECADE programme, Maastricht UAC was also willing to replace the MADAP FDP system, and was conducting a short term re-engineering program for bridging the gap between the ageing system and a fully fledged new system.

A bilateral agreement was established between DNA and NATS for launching a common replacement program.

[35] The number of systems is presently the same as before implementation of ARTAS

Eurocontrol DIS/ATD decided to participate in the programme, bringing funds for a core FDP system that would be adapted for each national environment. Moreover, Maastricht UAC joined the ASP participants in this programme, called the Initial Development Program (IDP). Some other ATSP (AENA, ENAV, DFS) formed a Second Development Program (SDP) team, that would benefit from IDP some years later. At the same time, DFS was in the process of fielding P1 and the requirements for the VAFOR IT advanced FDPS were already available.

The eFDP/IDP programme has been launched with a Steering Committee chaired by DIS/ATD, a Project Management Cell hosted by Eurocontrol, and project teams with each participant.

The global programme phasing was broadly as follows:

- Phase 1. Preparation of the Call for Tender.
- Phase 2. Project Definition
- Phase 3: Development and implementation of common and national adaptation systems.

Phase 1 has been decomposed into several work packages.

The programme was stopped shortly before the end of phase 1.

3.3.2.2. Positive results

A partial functional specification was produced, and included in the CfT as background material.

Discussions have allowed the definition of new alliances between partners that have led to bilateral specifications and call for tenders.

3.3.2.3. Negative results

Budget overrun and delay increase were observed. In general, efforts spent on tasks have been far larger than estimated. Delays have drifted accordingly. Frequent meetings in Brussels, Toulouse, London, raised travel expense significantly. Two problem areas are detailed below.

Operational requirements. The approach and method for capturing requirements and managing the analysis and controlling changes was not agreed at the beginning.

- Some participants were willing to have a limited number of high-level requirements. Other participants were seeking fine-grained requirements.
- Some participants were willing to have a strong requirement management method with computer tools. Other found it overkills.
- Eurocontrol was keen to have EATCHIP FDPD OR taken as a starting point. Some ATSP were in favour of a green field exercise.
- ATSPs were interested in having specific features recognised as general interest features and thus included in the common system scope. This led to variants inside the requirements.

The result was that the requirement capture process was very tedious, lengthy with regular monthly 2 day meetings. The requirement baseline amounts to more than 1000 requirements.

Functional specification. Prior to eFDP/Phase 1, Eurocontrol HQ and DNA had conducted FDP domain modelling (Ictinos project in France, EATCHIP III model at EHQ). DNA was willing to have some design constraints based on the Ictinos model taken into account, although they were not directly derivable from operational requirements. This was a source of debate and additional workload.

3.3.2.4. Possible causes

Antagonistic industrial approaches.

- Some ATSP have in-house strong technical teams that look deeply into the architecture of systems, so as to have maximum control of the development process and later of the maintenance phase. They express design constraints and tightly monitor the supplier's activities during the development phase.
- Other ATSP prefer to limit themselves to the operational requirements and the final acceptance, and leave a maximum design freedom to the supplier. Going further is considered over-specification.

Covert national industrial policy.

Some ATSP were suspecting that over-specification was used by other as a mean to favour a preferred supplier.

Poor cost/effectiveness of a consensus-based decision-making process.

The difficulty to reach a consensus on the content of the Call for tender and the risk that this could happen for other phases of the programme may have encouraged individual, or smaller size FDP programmes to be launched.

ATSP investments

Eurocontrol budget limitations lead Eurocontrol to ask the financial participation of the stakeholders. The participants did not want to invest in common solutions that cannot completely mastered.

3.3.2.5. Lessons learnt

The ATSP and Eurocontrol have currently too different objectives, methods, approach, organisations, policy concerning their relationship with industry to make possible the definition, procurement and development of big systems like the FDPS. It is very difficult to define efficient and binding decision-making procedures. The financing plan must be clear from the beginning.

The eFDP programme illustrates some of the common pitfalls of collaborative programmes.

A Collaborative programme survives in spite of its overhead when separate individual projects are not feasible.

3.3.3. AVENUE

Ref: AVENUE/Report_for_publication_10

3.3.3.1. Description of the project

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

- 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.

13 partners were involved in the project.

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

1. The definition of requirements specific to a validation platform by ATM validation platform users.
2. 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.

3. The definition of technical infrastructure based on the CORBA3 Component model.
4. 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.
5. The adaptation to this architecture of existing ATM components, provided by the 13 partners.
6. The integration of the components at the Eurocontrol Experimental Centre.
7. A technical exercise which aimed to demonstrate the capability of the developed facility and its suitability for large-scale real-time validation activities.

3.3.3.2. Positive results

- 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 of ATM 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 in this architecture (openness), to replace a component with another one (TP, MASS and in a parallel activity to the project, FDP) (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 a remote 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.

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 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).

It is worth mentioning however that even if the APIs that have been defined and demonstrated can be considered as *de facto* standards for validation platforms, a lot is still to be done to prove their suitability for operational systems. This is also the case of the technical infrastructure based on CORBA technology. A new system development strategy is necessary to enable to fill in the current gap between “pre-operational“ ATM systems aimed for validation purposes and the target operational systems.

3.3.3.3. Negative results

The following critical issues arose during the project:

- Strategic (lack of adherence to the EC objectives[36], external political issues, diverging motivation in the participation of the various partners)

[36] 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.

- 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) , of 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).

The complexity of the system architecture definition was underestimated.

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

3.3.3.4. Lessons learnt

Most of the lessons learnt are relative to management issues and could be applied to projects of this type (R&D only 50% funded by the EC).

The architecture of new systems based on common middleware and/or API, the definition of interfaces between components is challenging for research centres, ATS providers and Industry.

It is however very difficult in a group of 13 stakeholders plus the EC to have convergent objectives and interests, to agree on the role of each participant, to be equally motivated, and to be synchronised in the allocation of resources. The 50% funding is surely not an incentive to motivation. The partners also expect to be somewhat rewarded for their participation by gaining concrete outputs that they can use for their own business.

The need to involve all the key players and look for consensus is not compatible with short term efficiency. Technicians with a well-defined mission work well only when «political issues» do not permanently disturb them.

The contract must also be sufficiently flexible to easily accommodate adjustments in the course of the project to:

- objectives, if they proved to be too ambitious;
- partners' participation (including component delivery and effort levels);
- effort allocation to tasks (Work Packages).

There are always differences in working methods between the various organisations, and it is quite difficult to achieve a "pan–European" way of working.

But the criticism against this type of project, which is commonplace, can be tempered if you consider that an objective of these projects is the learning of a true working partnership culture, and the development of convergent objectives and interests, as important that the production of tangible technical results.

AVENUE not only gave interesting technical results that will be used in GTG but also helped to make a step in the direction of partnership culture.

4. INSTITUTIONAL AND LEGAL CONTEXT

4.1. Statement of work

4.1.1. Objectives

This Chapter deals with the current and anticipated regulatory and institutional environment as it could affect:

a) any project to provide flight data processing services across national European borders; or

b) the setting of new European design standards and FDP procedures.

We review the legal framework and the mandates and roles of key institutions.

4.1.2. Underlying Assumptions and Scope of Analysis

Flight data processing is a term with specific content meaning for professionals in the field. We must also define it in the broader legal and policy context. While our analysis tends to confirm that FDP can be regarded analytically as an integral aspect of air traffic control performance, we also make the assumption in this Study that FDP plays a particularly critical role in supporting and enabling the communications function.

Assuming FDP must also be viewed as an element of communications does not mean that laws and regulations governing aviation do not apply. They do. It does, however, mean that both general as well as aviation-specific rules governing communications and information may need to be considered. Especially the information-function of FDP suggests the need for a differentiated approach. From the beginning of international aviation regulation, States have accepted obligations to provide relevant information to actors in the international system, and a large part of ICAO's work has focussed on defining and organising the cross-border provision of data that organisations need to meet national responsibilities.

The appropriate development of FDP standards must also be seen as an aspect of a sound, market-responsive approach to European air traffic services provision and the legal establishment of the Single European Sky. Moreover, because of FDP's high technology content and development costs, rules and policies applying to development and investment will also be considered.

In this chapter we review:

- The historic and ongoing role of ICAO and its implications for EU action;
- The position of European aviation institutions, notably Eurocontrol and also ECAC;
- The application of current and contemplated EU regulations (including the draft regulations to establish the Single Sky);
- The likely development of Eurocontrol responsibilities upon entry into force of the 1997 Revised Convention, henceforth: the 1997 Revised Convention;
- Other developments that might influence Commission policy on FDP, including the implications of September 11th, as well as the national security concerns of European States;
- The role of more specialised bodies with mandates – or demonstrated organisational precedents – that might apply to FDP organisation and regulation such as the PRC/PRU, Eurocae, the CFDSG, the CFMU and EAD;
- The current legal setting as it could affect the assignment of liability for FDP service provision.

The broad question posed by this analysis is: To what extent have political and economic developments occurred and perhaps even been codified that will permit, facilitate, discourage or prevent the realisation of objectives described elsewhere in this Study? What forms of institutional and/or legal action seem logical and reasonable to pursue?

4.2. The ICAO Setting

Sometimes analysts or critics of the Chicago Convention on International Civil Aviation (henceforth: the Convention) are prone to dwell on its perceived emphasis on national sovereignty (Article 1) and argue this as a basis for restricting the scope of international and supra-national organisation of the ATM function and its various aspects. Such argument can cloud the basic meaning of the Convention, which is to establish obligations by its signatories to promote safe, fair and economic development of international civil aviation (Preamble). Moreover, if sovereignty would be the overriding standard for States in their international conduct, the rest of the Convention, including the Annexes as well as all other aviation conventions, would become meaningless.

Through its Annexes (established pursuant to Article 37), the Convention, moreover, has become a living document; ICAO's Council, permanent staff and special committees are constantly at work with the Member States to create or adapt Standards and Recommended Practices (SARPs), which oblige or guide the behaviour of Member States as well as private economic actors. Nowhere has this been more evident than in the area of communications generally and flight data specifically. Here Article 28 of the Convention established broad requirements whose need for periodic updating was (already in 1944) anticipated:

Each contracting State undertakes, so far as it may find practicable, to:

1) *Provide…radio services…and other air navigation facilities to facilitate international air navigation, in accordance with the standards and practices recommended or established from time to time pursuant to this Convention;*

2) *Adopt and put into operation the appropriate standard systems of communications procedure, codes…and other operational practices and rules which may be recommended or…*

3) *Collaborate in international measures to secure publication of aeronautical maps and charts in accordance with standards which may be recommended or…*

Many of the 18 annexes are significantly devoted to establishing standard communications formats for a range of operational and technical matters. Annex 10 *Aeronautical Communications*, with its five volumes, is by far the largest compilation of rules and procedures in the ICAO system, and *inter alia* it applies directly to the design and operation of FDP systems. ICAO's emphasis on communications standards has several implications for programmes and policies discussed in this Study:

1) The enhancement of uniformity of cross-border procedures is an historic priority and clearly in the spirit and the letter of the Convention;

2) The adoption of any regional procedures that would complicate compliance with global standards could, however, be a problem, especially if the consequence were to impose unique costs (e.g. for special avionics equipment) for non-European users of European airspace; however,

3) Nothing in ICAO rules and practice prevents a state or group of states from exceeding ICAO standards within their jurisdictions, as long as compliance requirements for third parties are reasonable and do not discriminate unfairly.

Thus, standardisation within the EU and Eurocontrol areas leading to consistency of flight data would support goals to which European states, as members of ICAO, have long committed to.[37] At the same time, an interoperable relationship with neighbouring regions and in the global system must be pursued and enhanced.

[37] See Preamble 6 of the proposed Regulation on the creation of the single European Sky (2001/0060 (COD), also referred to in 5.4.1 below).

4.3. Traditional European Aviation Institutions

The European Civil Aviation Conference (ECAC) established in 1955 has placed increasing emphasis on the need to strengthen European air traffic management. This need was of course the *raison d'être* for the establishment of the European Organisation for the Safety of Air Navigation (Eurocontrol) created in 1960. While we cannot begin to review the entire relevant history of the work of these organisations (which will also be familiar to many readers of this Study), their failures and their successes form part of the essential context for proposing and implementing future institutional reform.

Key aspects of this essential context are:

- The development over time of an extensive and intricate network or web of expert fora, relationships and organisations (including the EEC Brétigny) which have supported careful and imaginative systems development planning as well as stimulating definition of high professional standards;
- With the end of the Cold War and growth of global and European air transport services and systems, expanded scope for both ECAC and Eurocontrol – witness their dramatic growth in membership – as well as the assumption of direct European service responsibilities through the establishment of institutions like the CFMU and the PRU;
- At the same time, difficulties of these organisations, given the limited scope of their political mandates and their substantial historical dependence on consensus, to resolve the stubborn problems of national systems' integration and the bottlenecks that have held back timely response to market demand;
- For the specific purposes of this Study, we note that the traditional co-operation-based approaches of European states acting through ECAC and Eurocontrol have been unsuccessful just when they failed to elicit full co-operation and participation, notably full sharing of information.

Full sharing of information is a critical point of departure for (to use Vaclav Havel's phrase) "naming the problem." Design and development of new flight data processing systems (including conceptualising how they can be linked backwards and forwards to legacy systems and new adaptations) requires extensive and expensive research and development work. And that work – and the investments it is designed to support – will only be truly efficient if co-ordinated. High costs of ATM modernisation have been created *inter alia* by investments that failed to lower unit production costs (and were thus, by economics' definition, "inefficient" investments).

Problems of flight data consistency, that Eurocontrol is presently investigating, quite probably stem at least in significant part from historic lack of development planning consistency. As made clear by ECAC's *2000+ Strategy*, cost-effective modernisation depends on co-ordinated R & D.

"The Eurocontrol Agency may use the leverage effect of its R&D budget to provide incentives to projects compliant with the Strategy. In this way it can play a major role in ensuring that R&D is delivering the right products to the ATM programmes at the right time. The Agency's efforts must be supplemented by support from the European Commission's programmes…[38]

…A more concentrated sponsorship will deliver cost reductions through economics of scale…Enhanced co-operation, funding rules and competition mechanisms must be implemented as appropriate during both tendering and execution phases…

The main required actions related to R&D build on the relevant section of the ECAC Institutional Strategy and are:

- *implementing more effective ATM R&D co-ordination mechanisms across various European and National Organisations…*
- *collecting data on projects to determine the most efficient use of resources;*

[38] Member States of Eurocontrol have also agreed that it should "*co-ordinate the Contracting Parties' research and development programmes relating to new techniques in the field of air navigation, to collect and distribute their results and to promote and conduct common studies, tests and applied research as well as technical developments in this field.* See Article 2.1(h) of *The Revised Convention.*

- *maintaining R&D expertise in a distributed European network;*
- *concentrating R&D resources on the development and validation needs of the uniform European ATM network;…"*[39]

More than two years have passed since the adoption of these guidelines, but we still seem to be in the situation that no one possesses a clear overall picture about the scope, cost and nature of ATM R&D planning in Europe in general and with respect to FDP systems development in particular. At the January 9, 2002 Workshop, Eurocontrol representatives stated that information necessary to benchmark and evaluate the FDP systems development planning presently underway in Europe is not transparently available. Until we can systematically evaluate the costs and benefits of current practices, we are not truly in position to "name the problem." Unless and until we can name (and quantify) a problem, solutions in search of one are unlikely to enjoy success or acceptance.

4.4. Current and Contemplated EU Regulations

Regulations proposed by the European Commission [and endorsed by the Council] will formally establish the Single European Sky as a policy objective of the European Union and set forth rules and actions to achieve its implementation. This comprehensive undertaking (reviewed in more detail below) anticipates establishing both general (framework) and specific conditions that affect the development and operation of FDP services. The new regulations, moreover, build on or replace existing rules and policy statements. The Commission and the Council have recognised for some time the critical importance of ATM infrastructure for the free flow of persons, goods and services within the Community.

Examples of existing EU regulatory action in directly relevant fields include both:

- Basic regulations, e.g.:
  - Directive 92/50 on procedures for the award of public service contracts.
  - Council Directive 93/65/EEC addressing obligations of air navigation service providers to procure interoperable equipment
- And detailed regulations, e.g.:
  - Commission Regulation 2082/2000 of 6 September 2000 which adopts Eurocontrol OLDI and ADEXP communications standards into EC law, amending Directive 97/15/EC;[40]
  - Directive 98/34/EC laying down procedure for the provision of information in the field of technical standards and regulations.

The broad meaning of such legislation is: a) to indicate that Member State actions in the ATM field affect a European public interest; and b) to create certain standards of conduct.

The four new draft Single Sky regulations [whose formal adoption is now foreseen by the end of 2002] for the first time present a systematic vision of European airspace and its management from the Union's perspective. In the following subsections, we briefly review three of these regulations – the so-called "Framework" regulation, the Service Provision regulation, and the Interoperability regulation. The regulation on Airspace does not appear to contain provisions significantly applying to the specific themes of this Study.

[39] ECAC *Air Traffic Management Strategy for the Years 2000+*, Volume 2, pp 83-84.
[40] Note: This regulation as well Directive 93/65 will be superseded by adoption of the new Regulation on Interoperability.

4.4.1. Draft Framework Regulation [2001/0060 (COD)]

Proposed is a Regulation of the Parliament and the Council "laying down the framework for the creation of the single European sky", in this sub-section (2.4.1) referred to as: the draft Regulation. This document identifies "*fields of action*" for the three, more specialised regulations (referred to above); enunciates key general principles applying to these fields; and, importantly, describes relationships and mechanisms for the implementation and adaptation of regulatory goals and procedures.

The draft Regulation attempts to pursue EC and Eurocontrol objectives in a co-ordinated way; that is, the EC objective to create a Single European Sky, and the Eurocontrol objective to create a pan-European airspace.

The objectives of the Single European Sky Initiative are:

- Brings political will to change paradigms
- Creates new institutional framework
- Introduces competition for airspace and for service
- Streamlines the airspace irrespective of national borders
- Ensures interoperability
- Enhances safety and efficiency

4.4.1.1. Relevant general principles

In its Articles 5 & 6, the draft Regulation encourages co-operation among service providers and the establishment of groupings; it insists on regular consultations with users and transparency of accounts; it stresses the need for interoperability and harmonisation "*to ensure integration and consistency*" and it emphasises that:

> ***"****air navigation service providers exchange all data on the situation of flights during every phase of flight in order to facilitate operation of air navigation services; access to these data is open to all concerned on a non-discriminatory basis, without prejudice to safety requirements."*[41]

4.4.1.2. Relationships and mechanisms

The draft regulation takes "*into account Eurocontrol's mission to establish a pan-European airspace*" (see Art. 1(2)) and also envisages a structured relationship with Eurocontrol's Performance Review Commission to evaluate progress. In Article 8 (Relations with non-Community countries) it also foresees mechanisms such as bilateral agreements to extend the geographic reach of the Single Sky. Most importantly, the regulation creates a so-called Comitology mechanism, the Single Sky Committee, on which all Member States would be equally represented by a civil and a military representative. This Committee would be critical in establishing the bridge between aviation expertise and general policy and would be mandated to propose detailed regulations, e.g. "*implementing rules*" for Commission adoption.[42]

4.4.2. Draft Regulation on Air Navigation Services Provision

(in this sub-section referred to as the draft Regulation 2001/0235(COD))

This draft Regulation contains a number of provisions that would affect the design of future FDP service provision. These include:

1) Definition and/or description of the concepts of "bundled" and "ancillary" services;
2) authorisation requirements for forms of service provision covered under the Regulation;

[41] See Article 5 of the Draft Final Framework Regulation.
[42] See Article 7, *Ibid.*

3) requirements for regulating obligations among providers;
4) accounting and performance reporting requirements; and
5) rules for access to and protection of data.

4.4.2.1. Bundled and ancillary services

Annex I of the draft Regulation divides services into three broad categories: "**air traffic services", "other services"** and **"ancillary services."** Any named service within these categories is by definition an element of a "*bundle*," so that any provider offering two or more named services is providing a bundle of services (Article 2). In Annex 1 of this Regulation, **air traffic services** (ATS) are defined quite tightly. Except in aerodrome (terminal) control areas (where all aircraft operators presumably are addressed), they apply exclusively to control services provided to maintain separation among those aircraft operating under instrument flying rules and between such aircraft and obstructions (e.g. this would not seem to include any requirement for ATC to provide destinational navigational guidance).

"Other" services include search and rescue, meteorological services and aeronautical information. **"Ancillary" services** include communication, navigation and surveillance services. "*Communication*" is defined very broadly as "*a communication service provided for any aeronautical purpose*." Such a definition could, on its face, be interpreted to envelop functions like flight data processing outputs (which are only relevant if they are communicated). However, read in the context of the overall regulatory structure as presently being designed by the Commission, there is doubt whether FDP could qualify legally as an ancillary service or even as a discrete system, except when understood as a component of ATS.[43]

4.4.2.2. Authorisation requirements

The regulation introduces the concepts of "authorisation" and "designation" for providers of ATS over the territory of EU states.[44] A basic condition is that all ATSPs in future must receive a designation from the member state or states over whose territory they will provide ATC – implying a separation between the member state as regulator and the ATSP (whether public or privately owned) as provider. To be designated a provider must first be "authorised." In other words, authorisation and designation, seen legally, are two independent steps.

Very importantly, a European provider with a valid authorisation to perform services qualifies presumptively to perform these services anywhere within the EU and can be designated by a member state in which it is not domiciled (or chosen by a designated ATC provider to supply a supporting service). A pre-condition of authorisation, however (analogous to Regulation 2407/92) is that this provider be established within the EU; the rules would specify that: "*They [the providers] shall at all times be effectively controlled by such Member States or such nationals.*"[45] While authorisations will be issued by Member States, they must comply with "*general lines of approach*" set forth by the draft Regulation. These lines of approach (see Annex III) are broadly formulated but comprehensive; they create a framework for systematic and generally standardised quality expectations and control.

Finally, we must note that "**authorisation"** possesses a wider scope than **"designation."** As made clear in Article 8, whereas designation applies to the granting of exclusive franchises in airspace blocks, authorisation also permits offering unbundled services (e.g. "other" services

[43] See also discussion of the Draft Final Interoperability Regulation in 5.4.3 and 5.4.3.2 below.
[44] The term "designation" has a long history in air transport services agreements. Classically it denotes the formal naming (designation) by one party to a bilateral of an operator (airline) to perform services on the agreed air services that have been named or included by reference in the agreement. The other party is called upon to accept the designation unless it finds that the airline does not qualify because of failure to meet conditions enumerated in the agreement.
[45] See also Article 4(2) of Regulation 2407/92 on licensing of Community air carriers.

like AIS and ancillary services) without independent designation. For example, in Article 8 (3) it is expressly foreseen that the provider of ATC and ancillary/other services within a designated airspace block need not be the same person.

4.4.2.3. Regulating obligations among providers

Article 9 of the draft Regulation begins with the following statement: "Air navigation service providers may avail themselves of the services of other service providers, in particular for ancillary services, meteorological services and aeronautical information services." The phrase "of the services" is general and arguably would seem to offer scope for a specialist in FDP to provide facilities and services to other ATSPs.[46] This Article further stipulates that the provision of supporting services will be covered by agreement among ATSPs. Therefore not foreseen in the present language is the subcontracting of responsibilities to an organisation that lacks authorisation as a service provider (as described in Subsection 4.4.2.2 above and defined in the Regulation).

4.4.2.4. Accounting and Performance Reporting Requirements

Article 11 requires providers to keep "*separate accounts for each service listed in Annex 1.*" These do not include FDP (depending on interpretation of terms, see 4.4.2.1, end, and 4.4.3.2). However, the cost-base transparency requirements set forth in Article 14(3)© provide that "*standards shall be set out…including existing and future data…to conduct reviews…*" Moreover, Article 14(4) expressly foresees ongoing review of financial reporting requirements and tasks the Single Sky Committee to issue "*the necessary implementing rules.*" A stated goal of the charging policies is, moreover, "*to provide revenues to benefit projects designed to…improve collective air navigation infrastructures…*"

Arguably, these provisions taken together would provide latitude for the Single Sky Committee to require accounting practices that would enable cost-benefit analysis for any proposed collective change in infrastructure design and operation such as centralised FDP. Finally, pursuant to Article 16, the Single Sky Committee is also required to develop detailed rules for reporting on and analysing performance *inter alia* in order to "*allow the identification and promotion of best practice.*" This could be applied to the review of any pilot projects, for example, involving FDP services provided from a remote single point to a group of ACC's.

4.4.2.5. Data Access and Protection

Article 12 of this regulation lays the burden on individual service providers (Para 3) to establish "*standard conditions of access to its operational data from other service providers and airspace users*" subject to approval by national supervisory authorities. Other than mandating that data is to be exchanged in "*real time*" between providers and users and including a non-discrimination provision (that covers providers, airspace users and "*other operators*" undefined), this regulation establishes no qualitative standards. Nor does it provide any explicit guidance on data protection. Though textually longer, the language here if anything seems less precise than the general principle stated in the Draft Framework regulation (see 5.4.1.1 above). There seems to be some indecisiveness here as to the extent of the desirability of European-level regulatory involvement. At the close of the Article, further action is foreseen for the Single Sky Committee to recommend "*detailed rules [relating to standard conditions]…where appropriate…"*

4.4.3. Draft Regulation on Interoperability

Provisions in this regulation have both a wide and detailed application to the fields of analysis addressed by this Study. Thus we address its relationship to the development of the specific

[46] Had the language of Article 9 read "air traffic services" instead of services, there could be a problem, inasmuch as the latter term is formally defined in Article 2 as having to be a service named in Annex 1, where flight data processing services are not named. - see also 5.4.2.1, end.

technical standards as well the specialised institutional approaches needed for that in Chapters 6 and 8. Here we shall focus on the broader structure of the regulation and on how the flight data processing function is to be understood legally.

4.4.3.1. Policy Priorities

While each of the four draft regulations expresses a clear and strong statement of policy, the draft Interoperability regulation in a way tackles the widest range of policy issues – addressing as it does industrial as well as air transport policy. Under its "whereas" clauses, it stresses, for example, the need for a "*new partnership approach allowing the balanced involvement of all…[leading to] a coherent set of Community specifications that can fulfil the widest possible range of needs….*"[47]. Perhaps a bit more than the other regulations, this regulation envisages specific roles for Eurocae and especially Eurocontrol in providing regulatory process assistance, under the assumption that onward regulation, i.e. issuance of standards and so-called "implementing rules," is particularly important in this area. As such, establishing an institutional relationship with the Eurocontrol Notice of Proposed Rulemaking (ENPRM) process could have strong relevance for the implementation of this regulation.

Finally, it may be important to reflect on the role and character of the so-called "Essential Requirements" (specific applications to FDP discussed below) named in Article 2 and set forth in Annex II. Rather than being detailed, specific do's and don'ts, these are in fact (even when sharply formulated) statements of normative standards or policy objectives. Thus the main body of this Regulation which tends to focus on (also very important) areas of procedure, is actually not where most of the content and scope of interoperability needs are set forth. This is also why implementing rules indeed will be needed in order to establish specific regulations for the conduct of processes and conformance to standards.

In relation to the establishment of standards, the introductory communication on the creation of the Single European Sky (para 4.2 - third item on page 9 of) mentions: " the drafting of European standards and/or Eurocontrol technical specifications representing the lower level of the regulatory process of ENPRM and implying the consensual agreement of stakeholders on standards of voluntary application".

That lower level is not intended to become part of the proposed draft regulations, since the very purpose of the whole system is to limit the scope of the regulation at the second level (the implementation rules). However, the implementation of such standards is a key ingredient of a successful system harmonisation approach.

Our understanding is that the "implementation rules" have been introduced in the new regulatory model proposed by the Commission as a means of plugging the potential traceability gap between the high level "essential requirements" and the lower level "technical specifications and European standards".

When we discuss (at chapter 7) the definition of the FDP standardisation process we talk about "voluntary standards" to make it clear that what is to be developed is precisely that lower level "implying the consensual agreement of stakeholders on standards of voluntary application", a level that is not directly incorporated in the Draft Regulation, but which is expected to be traced back to the "implementation rules".

4.4.3.2. The Systems Position of FDP

The draft Interoperability regulation divides the air traffic management network into seven systems. These comprise the "*equipment and procedures*" for: 1) ATFM; 2) ASM; 3) ATC; 4) Communications; 5) Navigation; 6) Surveillance; 7) AIS/Met. FDP is mentioned but as an element of: "*3. Equipment and procedures for air traffic control, in particular for flight data processing systems, surveillance data processing systems and human-machine interface.*" [48] As such, this regulation defines FDP as a distinct but also core element of ATC (i.e. as an air

[47] See Preambular paragraph (7), Draft Final Regulation on Interoperability.
[48] See Annex I, *Ibid.*

traffic service under Annex I of the draft ATSP Regulation discussed under 2.4.2. above and thereby, by inference, not classifiable as an "ancillary" service).

4.4.3.3. The "Essential Requirements" as applied to FDP

Flight data processing performance receives particular, indeed central, emphasis in the important Annex II of this regulation. This Annex consists of two parts: General and Specific Requirements. The "General" section contains the following language:

> *"Seamless operation can be expressed, in particular, in terms of information exchange, common understanding of information, comparable processing performances and the associated procedures enabling common operational performances agreed for the whole or parts of the air traffic management network."*

This language, while it governs all seven systems' areas listed above, truly applies to FDP, arguably implying that FDP performance becomes a key, if not the key, area for meeting a central criterion of the Single Sky namely that "from the user's perspective…[the whole system] functions as if it were a single system."49

In Part B "Specific Requirements," the regulation lists a number of criteria for FDP performance which, in accordance with Article 15, would have to be met by 1 January 2009 by all providers. These include "seamless operation" in all phases of flight and support for the implementation of new systems of operation (e.g. CDM and "delegation of separation responsibility to the airborne side"). FDP systems are also tasked to support "integrated civil-military operations."

4.4.3.4. FDP development areas not addressed by this regulation

Notwithstanding the policy statement introducing this regulation cited above, neither the main text nor the Annexes clearly establish rules or policies for co-operation in the planning and development of new systems. Article 14 does commit the Commission to work on the definition of a "future concept of operations" and to consult stakeholders in the context of a "widely supported strategic management programme." However, no provisions appear to stipulate sharing of information, co-ordination of research or a commitment to consider, if not substitute, joint planning and specification in order to achieve efficiency of investment.

Finally, in the area of procurement policy and notwithstanding the economic policy concerns addressed in its preambular paragraph (7), the draft Interoperability Regulation does not really build a platform for addressing problems such as the adapting-to-the-local-market costs of *"national technical specification"* and the *"slowing down [of] the pace of introduction of new operational concepts…"*

Modularity is not addressed from an economic policy perspective; nor is it mentioned under the "General" Essential Requirements. It is referred to only in the Specific Requirements for ATC (that include FDP) in subsection 3.1.1 "System construction principles" which reads: *"Systems shall be designed, built and maintained on the grounds of sound engineering principles, in particular those relating to modularity supporting interchangeability of constituents*".

Relating modularity only to engineering principles will not create a basis here for economic regulatory actions intended, for example, to open competitive markets or for establishing design economies more conducive to phased harmonisation and modernisation of divergent systems. From the perspective of classical economics, modularity expresses in a modern form the concept of division of labour; it facilitates opportunity for specialist suppliers who can produce given constituents cost-effectively. It thereby also increases scope for competition. Finally, in an industry marked by rapid technological change, modularity is an increasingly important economic enabler for efficiency of investment.

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[49] See definition of "seamless operation" as contained in Article 3, Draft final regulation on Interoperability.

Regulating procurement to require modularity is a sensitive question, since, for example, the "turn-key" approach (i.e. dealing with a single, general systems supplier) has the attraction of concentrating accountability. On the other hand, it may be reasonable to establish general criteria in regulation to facilitate competitive supply and timely substitution of constituents and even systems and to do this without excluding the option of turn-key procurements. Therefore, modularity might be approached as a "general" essential requirement, i.e. a general norm, while opening the possibility for further regulation or implementing rules based on market and performance analysis/review.

4.5. Eurocontrol's role under the 1997 Revised Convention

The 1997 revision of the Eurocontrol Convention has yet to come into force. However, with the EU's and its Member States' accession to the 1997 Revised Convention (that is foreseen co-incident to adoption of Single Sky legislation), the way should finally open for its entry into force, which will occur upon ratification by all State parties to the 1997 Revised Convention.[50]

Upon ratification, the Eurocontrol organisation will face a number of regulatory tasks – to be co-ordinated with the Commission, and, perhaps at a later stage, EASA. These include both the mandate to create rules in named areas, like ATFM, as well the critical institutional challenge to organise efficient, mutually supportive, processes with the Commission and its Single Sky Committee in areas like: monitoring, investigation, analysis, rule-making and resolution of problems of non-compliance. Eurocontrol's expertise can play a critical role in the development of responsive, cost-effective regulation which the Commission is uniquely positioned to enforce for its Member States.

Terms of the 1997 Revised Convention also create new voting rules in the Eurocontrol Assembly -- that is, no unanimity required except in exceptional circumstances – that can facilitate extension of new rules accepted by the EU to non-EU members of Eurocontrol. However, especially in highly technical and technologically dynamic areas like FDP, it will be vital that – in the initiative and analysis phases of rulemaking -- Eurocontrol also provides the best kind of technical policy support to ensure that decisions are based on optimised professional information. This implies giving specific and stable structure, if not formal institutional form, to an integrated Eurocontrol Agency – Single Sky Committee relationship (supported by working groups and specialists) for conducting fact-finding, analysis and decision-making leading to new implementing rules or higher forms of regulation.

4.6. Other Recent Policy Developments

The institutional setting for adopting new policies in the acquisition, processing and delivery of data can be very quickly affected by technology changes, political and economic decisions (e.g. the decision to commit to the Galileo project) and external events, such as the tragedy of September 11th. The latter highlights the importance of strong regulations and institutions that can immediately and flexibly respond to national security concerns.

Fundamental changes or even adjustments in the systems design for flight data processing need to take public and national security into account and, desirably, improve current capabilities. A better and greater airspace situation picture extending perhaps well beyond the borders (especially of smaller states) is of mutual civil-military benefit.

For an Air Defence ultimately reliant on national data processing capabilities (to the extent that a European defence system does not yet provide alternative assurance), reliance on an external data processing system (especially without controllable fallback arrangements), is certainly a major concern. For that reason, achievement of requisite performance levels through the data warehouse/data switch approach (under which basic national capabilities must remain as essential inputs for the common system) seems a choice far more compatible with the current structure of defence policy.

[50] As of April, 2002, 11 States have ratified the Revised Convention.

Even in an evolutionary approach involving distributed systems, it will also be essential that design changes foresee safeguard arrangements and contingencies. Thus it is essential that the military participate appropriately in technical planning and policy development, both at the expert working level, through established co-ordination bodies at Eurocontrol, and at higher policy levels. In this context, the Single Sky Committee will become an important instrument to review the military as well as the civil implications of any regulatory changes that might be proposed affecting FDP organisation.

A topical issue for both public as well as national security interests is the access to flight data. There is unanimous agreement that all directly interested parties require full and timely access to operational data that determines movement in what is a public system. On the other hand, there is strong and growing feeling that especially current situation displays should not be made available to unknown, outside and/or unauthorised users.

4.7. Role of specialised bodies

A number of specialised bodies that have been or are becoming active at the European level in the ATM or FDP fields can play a direct role in – or provide examples for – institutional reforms applying to flight data processing. These include:

- EUROCAE
- The CFDSG
- The CFMU
- The EAD

The role of Performance Review Commission / Performance Review Unit will be addressed in Chapter 5.

4.7.1. European Organisation for Civil Aviation Equipment (Eurocae)

The European Organisation for Civil Aviation Equipment was founded in1963 to create a forum in Europe where administrations, airlines and industry could meet to discuss technical problems. Its members are comprised of aircraft manufacturers, avionics manufacturers, ground equipment suppliers, air traffic service providers and their regulators.

Eurocae started with the preparation of minimum performance specifications for airborne electronic equipment. This work was noted and supported from 1967 by ECAC, which later proposed to European national airworthiness authorities that they take EUROCAE specifications as the basis of their national regulations. Eurocae has thus become a successful standardisation body, mainly developing standards for aviation equipment in the airborne field. Its documents are considered by Joint Aviation Authorities and referenced by the JAA Joint Technical Standard Orders and other regulatory documents.

The increasing integration of airborne and ground systems have now required Eurocae to reappraise the scope of its standardisation activities, particularly in the area of air traffic management. This reassessment of strategy has been carried out in the context of the overall debate on future European policy and procedures (including the organisation of stakeholder involvement) for ATM rulemaking. The following main issues were investigated:

- **End-to-End Systems Integration** – the impact of complex interactions between ground and air systems needs to be included in the standardisation process.
- **European Standardisation** – the changing roles in aviation industry standardisation in Europe as foreseen by the European Commission and the need for Eurocae to be proactive in these changes. Methods of speeding up these processes and improving supplier inputs to standards were a key consideration.

- **Co-ordination with Related Bodies** – to ensure that relations with other bodies in the field such as **Eurocontrol** and **Cenelec** functioned supportively.[51]
- **Membership and Resources** -- the Strategy Task Force was asked to assess extending the scope of Eurocae membership and the cost implications of an enhanced standardisation role.

Significant findings included proposals that Eurocae provide technical standards for both air and ground systems and also establish a technical committee to make recommendations for new standardisation working groups. Tasking for two working groups were then defined that relate to ATM ground systems:

1. *WG 59 Flight Data Processing* whose mission is: “Interoperability standardisation of European Flight Data Processing,” and
2. *WG 61 ATM Open Architecture* whose mission is: “Development of the Standards of an Open Architecture for Future European interoperable ATC Systems.”

These two working groups clearly have assignments that will bear directly on the realisation of the EU’s proposed “Essential Requirements” for Interoperability.

4.7.2. Consistent Flight Data Sub-Group (CFDSG)

The CFDSG has been sponsored and convened by Eurocontrol in 2001 to help resolve problems of inconsistency of flight data used by systems in ATC Centres, the CFMU (including the IFPS) and other ATFM units, airports, airlines, other aircraft, associated systems, and military and air defence units, etc. This sub-group was established to:

- Consider the operational impact of inconsistencies in flight data available to stakeholders;
- Determine the causes of the inconsistencies; and
- Recommend operational, procedural and infrastructure improvements which will increase the consistency of flight data available to stakeholders to the highest level which is cost-effective, thereby having a lasting benefit for efficiency and safety.

The sub-group includes representatives from: Eurocontrol – including the CFMU and the EEC Brétigny; Air Navigation Service Providers; the supplier industry; airport operators; aircraft operators; Military and Air Defence authorities; and the European Commission. In addition to its analysis of FDP inconsistencies, the sub-group has been asked to:

- Identify constraints which stakeholders may face in evolving their systems (technical constraints and planning constraints) to ensure more consistent flight data;
- Perform a data analysis both for current requirements and for future requirements which are in line with approved operational improvements, to describe in particular the elements of flight data which need to be made common and consistent between stakeholder systems (making use where possible of existing data models);
- Analyse the implications and options for processes, procedures and system architectures, in order to improve the consistency of flight data available to users.
- Identify the advantages and disadvantages of the options, including commercial, institutional, regulatory, contingency, maintenance and transition aspects;
- Make Cost and Risk assessments for the identified options;
- Recommend options that will increase the consistency of flight data available to stakeholders to the highest level that is cost-effective. Where the recommended improvements can only be achieved in a medium/long term timescale, short-term work-around solutions may be proposed;
- Propose Standards to facilitate the implementation of the recommended options;
- Make recommendations for follow on work.

[51] CENELEC is the European Committee for Electrotechnical Standardisation.

The foregoing mandates and scope of work suggest that the CFDSG could, if properly co-ordinated and supported, develop comprehensive and formidable expertise and overall insight with respect to cost-effective FDP modernisation strategy at the European level.

4.7.3. The Central Flow Management Unit (CFMU)

To the extent that now, or at some future point in time, European service providers and regulatory authorities conclude that it has become advisable to centralise FDP provision (Option 2 in this Study), then one institutional model to consider would be Eurocontrol's Central Flow Management Unit (CFMU). The CFMU replaced formerly distributed systems of air traffic flow management with a central institution that has come to provide indispensable service. Operationally, the CFMU also depends on centralised submission of flight plans (IFPS) which in turn would serve as a vital input for centralised flight data processing. Thus there are clear conceptual analogies. All cases represent a scaling-up of information management and analysis.

On the other hand, the FDP function directly supports operational control of the individual aircraft, whereas the ATFM work of the CFMU is a demand management service designed to maintain safety and fluidity in the system. As such ACC's as well as ATSP's want direct managerial influence if not control over FDP performance.

The policy implication is that the user of a remote service may want not only normal rights as a customer but also direct influence, if not authority, over the further development of the product. A centralised FDP service organised and funded like today's CFMU would not facilitate this level of user control.

If, however, organisations like the CFMU were directly funded by their own customers as direct investors – or through a system of dedicated user fees – flexible, dynamic and direct accountability might be created.

4.7.4. The European Aeronautical Information Service Data Base (EAD)

Over the past two years, working through Eurocontrol, ANS providers from a majority of Eurocontrol Member States have agreed to establish a consolidator for processing and distributing aeronautical information, the European Aeronautical Information Data Service Base (EAD).

The primary aim of the EAD Programme is to develop and implement a central repository for all Aeronautical Data related to the ECAC Area.

There will be two types of clients: Data Providers and Data Users. Data Providers will supply the data that will be handled by the EAD and will include:

- The AIS organisations from CAAs, ANSPs and military administrations from the ECAC area,
- Designated Organisation maintaining data, which is not a national responsibility.

The EAD performs coherence checking of the data and then makes a consistent view available to the Users of the Data. At all times, ECAC Area States will maintain intellectual property rights over, and have control of, the data for which they are responsible.

Data Users will consult the data, which will be handled by the EAD. Typical Data Users will be:

- Data Providers,
- International Organisations,
- Aircraft Operators,
- Private pilots,
- Commercial User,
- Members of the General Public.

Possibly within the framework of a European Economic Interest Group (EEIG), providers and states interested in creating a joint FDP provider company should find this model interesting if not attractive. Following is a brief summary of legal/organisational elements as they currently seem envisioned:

- General management and oversight for EAD remains under the Eurocontrol umbrella (enabling policy review by Member States);
- Operations, however, will be subcontracted to a limited liability company organised under Spanish law located in Madrid, presently owned (one third each) by DFS, AENA and Frequentis, i.e. two providers and a manufacturer. Discussions are underway possibly to include other owners, but the three founders expect to retain 51%.
- The subcontractor will be economically and performance regulated by Eurocontrol through contractual provisions (including a service-level agreement). It has received a franchise for five years after which the services are to be rebid. It can earn an agreed return on invested capital. After an operating phase-in period, it will also be governed by a "bonus/malus" system -- i.e. financial rewards for good performance; penalties for bad.
- Formal start up of EAD at Madrid is expected for summer, 2003. So far 18 Eurocontrol Member States have committed to participate and two others are leaning toward. Eurocontrol would welcome a European regulatory environment that stimulates 100% participation of its 30 Member States.
- To overcome a tricky management and control issue on data integrity, EAD has adopted a process by which it will be responsible to identify conflicts in data inputs (especially affecting cross-border operations) through application of so-called "validation rules." EAD will then notify the state(s) concerned and ask for corrective action. The integrity of the final data delivery remains, however, the legal responsibility of the originating state.
- Insurance issues. The construct described above results in the following liability insurance plan: Member States remain responsible for data input. The subcontractor is responsible for processing. Eurocontrol is responsible for system function. It is not planned for the subcontractor to carry any independent insurance; he is to be covered by Eurocontrol's general insurance.
- Oversight. As indicated above, within its powers and scope, Eurocontrol acts as regulator of performance. It will also have an interest in supporting binding EU regulation, e.g. in the area of interoperability, that favours adoption of a interface standards such as AIXM that could then stimulate the market development of interoperable end-user systems.

4.8. Liability for the performance of FDP

Liability for the adequate performance of FDP must be distinguished from *responsibility* for the adequate performance of FDP. In our opinion, Article 28 of the Convention (quoted in Section 2.2 above) governs *responsibility* for the adequate performance of FDP. It follows that *States* are responsible for this task.

Concerning liability, the following questions must be addressed:

(1) who are the liable parties;

(2) for what can they be held liable;

(3) on what legal basis;

(4) how to identify practical solutions?

4.8.1. Parties involved in the liability chain

The parties involved are at least the ATSP and the operator of the aircraft (see also, the contractual chain mentioned under (4) below). In most cases, the aircraft operator will be a commercial aircraft operator. However, the receiver of the data can be an operator of a military aircraft, or private aircraft engaged in general aviation activities.

<u>Damages</u>

Liability questions arise when the activities attributate to the parties mentioned under (1) above cause damage, e.g. if the ATSP causes damages to the operator of the aircraft because of deficiencies in the FDP process. The damage must be material damage; the incurred losses must be expressed in terms of money.

Basis of liability

In the vast majority of cases, there is no contractual link between the ATSP and the operator of the aircraft. As far as we know, New Zealand is the only country in the world, which has established a contractual relationship between ATC and the operators of civil aircraft. Consequently, the cases following from (1) and (2) above will have to be based on *tort* law. Attempts to draw up a liability convention for ATC on a global basis have so far failed.

Practical solutions

Liability of the potential FDP operator for negligent commission or omission is a major unresolved issue. In the US, governmental liability in a field that is related with FDP, namely, GNSS, has been accepted, with certain restrictions. In some States, sovereign immunity issues play a role. Thereby, it would seem that governmental liability flows from governmental responsibility as established by the above mentioned Article 28 of the Chicago Convention read with national legislation on the subject.

However, there are tendencies to examine the subject of liability of organisations providing services for international civil aviation, including also ATC and GNSS, from the angle of the *contribution* made by each of the actors involved. Eurocontrol and some national authorities are currently investigating the notion of "*contractual chain,*" that is, a mechanism to properly allocate liabilities between the various actors in this area.

The purpose of the *contractual chain* concept is to establish liability for each stakeholder in the chain of the operations, taking into account the most "genuine" link between the stakeholder and the damage so as to avoid that a stakeholder bears the liability which should have been borne by another actor. The EC Commission supports the contractual chain concept drawn up by Eurocontrol.

4.8.2. Concluding Observations on Liability

It seems to us that liability for FDP must be seen in the context of service provision to the operation of international air services. European organisations (see, previous subsection) claim that such service provision should be governed under the "contractual chain" concept. The establishment of the *most genuine* link between the actor or service provider and the damage that has been caused should provide the basis of liability. Absent an international regime, national law, in combination with private international law, must give solutions. In considering which national law applies, the legislation of the country "most genuinely linked" with the damage and with the actors having caused the damage should in principle form the legal basis for the settlement of claims. Therefore, decisions pertaining to the choice of law and most appropriate forum to judge the claim would be determined on an *ad hoc* and case-by-case basis under private international law.

4.9. Summarising Current Legal and Policy Trends

The individual technical systems that collectively comprise the infrastructure for European ATM performance have continued, for the overwhelming part, to be developed and operated nationally, even though Member States have long since committed themselves to the idea of European-level service standards and performance. The Single Sky initiative responds to the need to make rhetoric into reality.

Decisions to be taken in future FDP investment must respect this European performance dimension. The new Single Sky regulations tackle this at two broad levels:

1. The encouragement of **individual initiative** on the part of individual providers to innovate across borders;

2. The strengthening of **collective responsibility** to establish, maintain and enforce common technical standards.

The idea of partnership is central to both individual initiative and collective responsibility. Thus the expertise and institutional structure that has developed under ECAC and Eurocontrol will remain valuable, indeed essential, especially to the degree that its operations reflect partnership and full commitment to provide timely and cost-effective solutions, pursued where technically advantageous through joint action.

The Single Sky Committee to be created by EU legislation is positioned both to stimulate innovation and safeguard traditional interests. It is simultaneously an implementation mechanism empowered to design rules to achieve performance standards called for in the new legislation and a body positioned to review ongoing developments and recommend adjustments and innovations. A carefully crafted partnership with Eurocontrol will be indispensable in establishing quality controls and in gaining acceptance for its decision-making.

Especially (but not only) with respect to FDP systems innovation, competent European institutions in partnership with Member States, providers and other stakeholders may conclude that further steps are needed beyond the first package of Single Sky regulations. Areas of the present and contemplated law that may need such further attention (and as discussed further in other Chapters of this Study) include:

1. The issue of co-ordinated research and development specifically identified by Member States in the *ECAC 2000+ Strategy*;
2. Information policy: Further rules on flight data access may need to be adopted to address possible gaps in the current legislation.
3. Modularity and the possible establishment of economic as well technical design criteria;
4. Clarifying and standardising ATM systems performance liability (note: a selective liability approach to the FDP function would not make sense for numerous reasons).

5. TOWARDS COLLABORATIVE DEVELOPMENT AND PROCUREMENT

5.1. Statement of work

5.1.1. Objectives

The technical programmes that have created additional capacity and improved safety over the past decades have suffered from laborious decision making and inconsistent implementation. It takes a long time to agree on important steps to be taken, and too often the agreement does not translate into actual commitment by all parties concerned to implement it.

This chapter discusses the types of collaborations that should be encouraged throughout the system definition life cycle, including FDP specification, development and procurement, in view of a more efficient implementation of FDP systems in Europe.

Activities after the system implementation stage, i.e. related to the FDP service provision, even if they are not independent of system procurement, have been treated in a separate chapter (chapter 6).

The resulting recommendations are not specific to FDP, and in most cases, can be extended to CNS/ATM systems projects as exemplified in the last section of this chapter. The discussion is not restricted to “low level” system engineering considerations; it takes account of the overall regulatory context and organisational framework.

5.1.2. Key issues and approach

Is tradition an asset or a burden?

The stakeholders’ views relative to the strategy to be applied for improving ATM performance mirror diverging opinions concerning the Europe of tomorrow, its degree of political integration, the distribution of power levels, societal choices.

This helps to understand heaviness or reluctance that reflect legitimate concerns, and to accept differences, compromises and a “small steps” policy.

It is now an opinion shared by most of the stakeholders that the improvement of ATM (organisation, system definition, development, procurement and operation) depends on an improved co-operation between all ATM partners based on trust and mutual understanding.

The findings of our stakeholders’ inquiry on the issue of collaboration can be summarised as follows:

- nearly unanimous support for modular specification,
- nearly unanimous support for shared procurements made on a voluntary basis,
- unanimous support for enhanced standardisation,
- solid support for EC-led regulation,
- but, significant resistance to specialised FDP service provision.

Our approach is guided by a pragmatic attitude not aiming every time at a full consensus, but relying on the driving power of successful results.

This is in line with the spirit of the proposed new Single Sky regulations, i.e. the encouragement of **individual initiatives** on the part of individual providers to innovate across borders, and the strengthening of **collective responsibility** to establish, maintain and enforce common technical standards.

This chapter is split in four sections:

- Section 5.2 assess some recent initiatives envisaged for a better integration;

- Section 5.3 discusses the types of collaborations that should be encouraged given the sensitivities involved, the degree of stated readiness for co-operation and legal latitude;
- Section 5.4 extends the approach to other collaborative projects deemed relevant.
- Section 5.5 recaps the recommendations resulting from the previous discussion.

5.2. Assessment of some recent initiatives

5.2.1. The concept of "Functional Blocks" of Airspace

The introduction of functional blocks of airspace is an attempt by the Commission to reduce fragmentation. Even if the concept of "functional block" may not be entirely defined, the idea is to enable service providers to exercise their responsibility over larger, rationally configured blocks of airspace and not constrained by traditional political geography. The extract below is taken from [D9].

Joint proposals for functional blocks of airspace will be made by the service providers and the Member States concerned. These proposals will be reviewed by Eurocontrol to check for consistency with overall airspace architecture and for compatibility with neighbouring zones. Where the proposal can be supported, it will be adopted by the Commission.

The responsibility for designating the service providers in charge of managing functional blocks of airspace rests with the Member States concerned. Member States will decide for themselves how designation occurs. They will have a choice: they need not necessarily continue existing arrangements, but they can designate providers from other Member States either alone or in a co-operation with the incumbent. They may designate one provider for part of their territory and another for another part. Member States may even, if they wish, consider a selection procedure that enables them to make the right choice. Where a functional block of airspace extends over the airspace of several Member States, these will need to take a joint decision. In that case the service providers will have established a form of co-operation to handle the traffic in the functional block of airspace. That co-operation can be organised loosely, or could evolve over time to a real integration.

Fragmentation must also be reduced in respect of ATM systems. It could be expected that integration of service providers will lead to more integration of systems.

At Maastricht 2002 exhibition, IFATCA showed how this could materialise [D11]. This possible solution is illustrated below for information only.

The creation of multi-national centres such as CEATS, NUAC is in line with this idea. There are also local initiatives in the direction of larger blocks like in Switzerland (which is developing its own Alps Functional Block) and Italy (which has recently transferred the Milan and Brindisi upper airspace to the Rome centre). A few ATS providers, especially those with a market-driven form of organisation, see here a real opportunity for future developments.

However, this proposal does not get a wide acceptance from the stakeholders. Most of the key players in the core area are not ready to accept a change from incumbent ATS providers. And some States having implemented several en route centres inside their national borders for years are firmly opposed to a modification of this organisation.

We have already illustrated this kind of blockage through the case of ARTAS discussed in Chapter 3. ARTAS failed to achieve "a fully seamless system" made of ARTAS units independent of national borders because States hid behind the necessary protection of their sovereignty rights and safety. ATSPs wanted to keep full control over their systems.

The consolidation of ATS services into functional blocks is likely to become a reality only once the technical conditions to facilitate the economic integration will be met. Thus the consolidation of FDP (and other systems) interoperability should be pursued as part of a broad but also prioritised basic strategy with deadlines to achieve the Essential Requirements of "seamlessness" (see also Chapter 4).

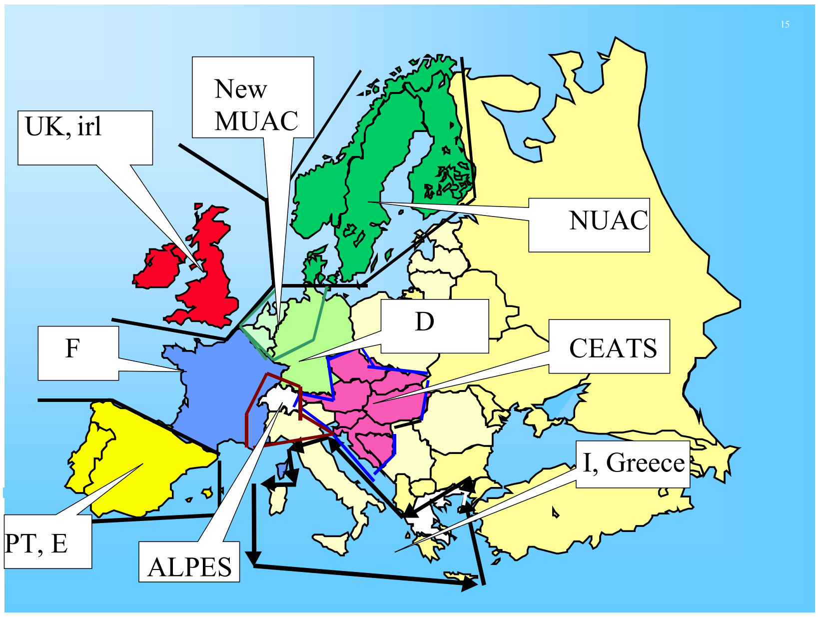

Figure 5.1: IFATCA view of Possible Functional Blocks of Airspace

☞ To be successful, the de-fragmentation of airspace should rely not so much on a general top-down approach to reducing the number of fragments, but on a focussed and stepwise effort to integrate the workings of the fragments by a better standardisation of systems aimed at making them fully interoperable.

☞ The harmonisation and optimisation of operational procedures has to be encouraged. It would lead to reduced personnel cost due to the fact that this would allow a better scheduling of resources (one controller being able to be licensed for more sectors). A very important point is that this would procure a uniform controller-pilot interface, giving an evidence of seamlessness.

5.2.2. The notion of interoperability

The idea of a better interoperability between ATC systems, as well as between ATC systems, CFMU, airlines, military and airports systems, is now largely admitted as enabling real gains in capacity, and probably also safety.

☞ The groups of EUROCAE dealing with ATM ground systems interoperability, namely WG 59 Flight Data Processing[52] and WG 61 ATM Open Architecture[53], have to be encouraged by appropriate funding, especially to guarantee an active involvement of industry and ATSPs.

Improved interoperability implies increased data sharing and more responsive data updating. These enhancements can already be supported by current systems generation, but the notion

[52] Interoperability standardisation of European Flight Data Processing
[53] Development of the Standards of an Open Architecture for Future European interoperable ATC Systems

of interoperability is meaningless if there is no consensus on the operational requirements, the underlying system architecture and the mutual roles of systems in data exchanges.

The actions driven at upper level by Eurocontrol on the EATMP High Level Requirements and Overall Architecture are therefore essential.

☞ An overall co-ordination/liaison of the various working groups involved in the ATM architecture definition, ATM architectures standardisation, and ATM systems interoperability (Eurocontrol, Eurocae, CFDSG) is needed to ensure technical consistency and avoid overlap or duplication of work.

Other measures to bolster the standardisation and certification process are examined in detail in Chapter 6.5. Our recommended policy line is to facilitate co-operation, consensus and timeliness of action:

- with standards defined at the "right" level, i.e. sufficient freedom should be retained for ATS providers in the detailed specification, and for industry in the details of technical solutions.
- by giving precedence to efficiency over "aesthetic" considerations (stick to clients needs, and keep it simple).

The role of the systems being defined, as well as the data to be exchanged, an implementation plan must be defined. Measures must be taken to monitor and enforce the decisions taken. Incentives are also important. While it will not be simple to reward efficiency practices qua efficiency practices (e.g. as opposed to rewarding final service performance), ATM charging/costing principles should be reviewed so that efficient investments that create interoperability result in net benefits for providers as well as users.

5.2.3. The concept of "consistent flight data environment"

The CFD Sub Group has been created upon cancellation of the former EFDAS feasibility study on the grounds that it was too limited in scope. The sub group is tasked to recommend options to increase the consistency of flight data available to stakeholders to the highest level which is cost-effective.

These recommendations will be the culmination of a considerable analytical work - only just started - centred on examining the difficulties caused by different qualities of flight data being provided, and assessing the options to improve the data consistency taking account of commercial, institutional, regulatory, contingency, maintenance and transition aspects. It is expected that the time for this work will be approximately 1.5 - 2 years.

The "CFD Concept", which has already been tabled, is based on a logical "Common Flight Object environment" where European-wide consistent Flight Data could be made available.

Even if it is already recognised that the foreseen advanced tools (e.g. multi-sector planning, sequencing tools, conflict resolution assistance) will request more data and with an horizon larger than procured by current interchanges[54], the need for - and feasibility of - a new architecture or new interoperability requirements are still to be proven (e.g. through modelling and prototyping). Also, past experience has shown that the architecture is a very sensitive point. Considering already at this stage a collaborative development in view of the validation of the "Consistent FD environment" is surely premature.

The CFD "steering committee", where stakeholders' representatives participate in the decision-making by consensus, is a correct forum to discuss the requirements for interoperability and data consistency. But such decision-making process is fragile, as one partner can block the progress of the group.

☞ The commitment of stakeholders to the CFD programme is not very clear (the TOR is not informative about this). The participation is based on good will and there is no

[54] It is anticipated that the OLDI messages will no longer be adapted since procedures will involve more sectors and more centres.

assurance that the participants represent significantly the full universe of stakeholders involved in the field. This point needs to be clarified by Eurocontrol.

☞ As already emphasised by some stakeholders, it is necessary to evaluate the consequence of inconsistency on safety and capacity, and to carefully balance the costs and benefits of solutions proposed. The experience show that engineers - even issued from ANSP - can build "gasworks" for controllers (e.g. too complicated MMI and procedures) where a mere phone call would have sorted out the problem. This is a field which requires very close co-operation with the users (controllers, CFMU operators, Airlines agents, etc…) to validate the solutions.

5.3. Types of collaboration

5.3.1. Collaboration in Decision Making processes

5.3.1.1. Regulatory framework

As the optimum solution for Europe is not the sum of individual optimum solutions, it is necessary to have integrated solutions and a regulatory framework helping decision making and enforcing implementation of prioritised solutions, after a large consultation of the stakeholders. A safer, more productive, environmentally acceptable and cost-efficient system must be the common objective.

The 1997 Revised Convention of Eurocontrol (and assuming the participation of the Commission as a member of Eurocontrol) for one part and the Commission regulations for the other part will reinforce decision-making, for example by transposing Eurocontrol measures into Community legislation.

Eurocontrol has already undertaken significant regulatory work, mainly in connection with airspace and equipment issues. Eurocontrol is now putting in place structures and working methods that will provide assurance that its regulatory work complies with requirements of objectivity and neutrality, through the establishment of a regulatory unit that is functionally separated from the rest of the Agency and through the institution of notice of proposed rulemaking procedures.

The European Community could provide a good platform for intensifying the participation of the stakeholders in the air traffic world, in particular the social partners in the context of the Community's well-developed social dialogue, and the manufacturing industry together with airlines, airports and service providers. It can also act to assure coherence of decision-making among air traffic management, air transport and airport policies, as well as industrial policy, the environment and, since last September, security [D9].

However the respective role of Eurocontrol, the Commission and the states regarding regulation remain to be detailed. Each organisation possesses distinct natural advantages and a different scope of action. While there is always the risk of duplication and even conflict, we perceive a logical allocation of roles that would lead to cost-effective regulation.

☞ The integration of regulation plans and the harmonisation of priorities could be most efficient. We recommend to co-ordinate and optimise efforts by giving the Eurocontrol Agency a structural role in the development of implementation rules and standards which the Commission will be uniquely positioned to adopt and enforce.

5.3.1.2. Performance monitoring

The ECAC institutional strategy (adopted in 1997) is a performance-oriented strategy. This is reflected in the revised Convention of Eurocontrol.

The European ATM system is meant to operate as efficiently under the “common performance scenario” (where service provision is distributed) as it would were it operated as a single unified system. This is the test of the success of this strategy.

ATM Strategy 2000+ requires that business cases be established for every proposed major change for cost benefit analysis to be applied before decisions are taken about their implementation. Capacity, safety, profitability have to be put “in the same basket”. Partnership has to be encouraged: all the stakeholders “in the same boat”.

5.3.1.2.1. Collaboration through benchmarking

The comparison of performance indicators between ATSP, ATS units, suppliers is a source of progress. It could explain the large variance of unit rates that exist in Europe. To select the “good reasons” (nature of traffic, military areas…) from the bad practices. This is not just an issue of how hard controllers work, or the quality of ANS Provider management, or the efficiency of civil/military co-ordination, or airspace design, or whether or not ACCs could be combined into larger units - it could be some or it could be all of these.

Established pursuant to provisions of the 1997 Revised Convention that could be implemented following signature, Eurocontrol's PRC (Performance Review Commission), supported by the PRU (Performance Review Unit), almost immediately began making major analytical contributions in the evaluation of ATM performance in Europe. For the first time, systematic benchmarking began to be applied, so that policymakers could see actual dimensions of problems on a Europe-wide basis. But the performance-oriented approach of the ECAC Strategy is still in its embryonic phase. Much work of course remains to be done, and all of PRC's work depends on reliable and adequate information.

The PRC has pioneered in introducing more systematic economic analysis to the ATM field. In its initial work (e.g. in PRR's 1-4), the PRC applied these techniques primarily to analysis and comparison of operating efficiencies (e.g. service provision).

Clearly, especially given the cost-history of European ATM, there is an equal if not greater need to apply such analysis to investment efficiency and to development planning/modernisation strategies. To do this, the PRC will of course require certain information. Arguably, ECAC/Eurocontrol Member States - on the basis of their formal adoption of the 2000+ Strategy as well as the 1997 Revised Convention - should feel obliged to supply the PRC with requisite data on their investment development and procurement costs. Despite the PC having adopted a PRC recommendation requiring ANSPs to provide 5 years forward looking business plans only a handful have complied.

☞ If that fails, the Commission should consider measures to require that EU Member and Associated States provide information that enables benchmarking and comparison of FDP development costs and procurement efficiency. It may also be necessary to issue reporting requirements to determine the current operating costs of performing the FDP function.

Until such information is comprehensively available, the costs/benefits of externalisation - either of a public service central point (e.g. CFMU model) or a co-operative institution organised under private law (see EAD discussion) collectively serving many or some ATSPs - cannot be objectively evaluated.

5.3.1.2.2. Collaboration through transparency and communication

Defining a performance indicator is a difficult exercise, but its interpretation is an even more difficult task because it enables to grasp only one dimension of a problem which have much more parameters.

The setting-up of a continuous improvement cycle is based on information, which must be relevant, correct and equitable. But meaningful data will be made available only if a background of confidence between stakeholders has established.

The issue of co-ordinated research and development specifically identified by Eurocontrol Member States in the *ECAC 2000+ Strategy* need further attention. The Eurocontrol ARDEP database provides relevant but still partial information in that, for instance, it does not integrate R&D made inside Industry.

The Support To States (STS) department of Eurocontrol handles data concerning FDP developments in the Local Co-ordination and Implementation Plans (LCIPs) of each State. But they are also bound by confidentiality agreements and cannot diffuse the data largely.

Likewise, Eurocontrol had proposed [cf. C17] to develop and maintain an inventory of systems and products available from ATM suppliers (or in advanced stages of development) listing their technical and functional capabilities. To our knowledge, this inventory database has not been created.

☞ A complete picture of the current and foreseen developments in the FDP field, widely accessible, is still missing. It is necessary to achieve a global view of the objectives, planning and outputs of R&D and systems implementation programmes in Europe agreed on an individual state basis as well as collective basis. The EC could act for a better transparency between stakeholders in this respect.

This should help to highlight and promote best practices, and also favour harmonisation and convergence.

5.3.2. Collaboration in system development & procurement

5.3.2.1. Towards a partnership between industry and ATSP?

Industry has developed a thorough know-how in R&D and system development. On the other hand, ANSPs understand the “end game” in terms of service delivery requirements. Individually, ANSPs and Industry have enormous talent available. Value will be created from combining competencies of the Industry and ANSPs [D15].

With the separation between regulation and service provision and the advent of new forms of organization for ANSPs, a new partnership between Industry and ANSPs can be investigated. Partnership is more than cooperation: it is the ability to create value through operating two or more businesses as one in order to serve a common customer.

This requires first a change of culture, then governmental willingness to facilitate appropriate market conditions. Today, this possibility looks like “science fiction” at first sight. But the EAD project has shown that this approach was possible, and tomorrow it may become prevalent with the privatization of ANSPs. This is discussed more thoroughly in chapter 6.

5.3.3. Towards joint procurements?

The eFDP project has proved that the achievement of core high level specifications was possible. But this output was one bit of the whole requirements to be addressed which included also local functions and specific interfaces with other components (surveillance, CWP, etc.). The ANSPs involved came to the conclusion that the production of a common kernel was not worth it because a too substantial part of the system had still to be tailored-made for them.

The failure of eFDP relatively to ECAC-wide procurement shows that the reduction of the number of FDP servers should be left to occur through voluntary co-operation and market force rather than through regulatory enforcement. All that needs to be done is to make sure that the technical solutions retained for the future interconnection architecture do not preclude that reduction (and that implies stringent common interoperability and performance standards).

The multi-partnership FDP projects that are now under way must be considered positively even if they look at short term solutions or involve, in some cases, not more than two entities (e.g. Franco-Italian FDP). These projects do not target a true airspace integration, but they enable by construction a certain level of interoperability and a reduction of system development costs[55]. They retain competition between ATM suppliers and accommodate local requirements whilst taking the eFDP specifications as the cornerstone.

☞ The EC should (e.g. through TEN-T funding) encourage joint programmes aiming at a better connectivity between systems[56]. These developments could feed the work of standardisation groups, thus avoiding risks of divergence with standards being developed. This development work could also make up the bricks of a platform to validate the standards.

☞ The EC should give incentives to help phasing the upgrade of operational systems interfaces with newly published standards.

☞ The experience of ARTAS led Eurocontrol to modify its policy concerning the development of prototypes by Industry. It seems reasonable to retain double development (two companies in parallel on the same project) when affordable in order to sustain the industry knowledge and competency.

5.3.4. Collaboration in R&D

5.3.4.1. Industry – Eurocontrol – European Commission Partnership

5.3.4.1.1. General

The EATMP, as conceived to date, may be kept as a reference specification for future procurements to be effected by ANSPs as systems go though their life cycle. However an abstract specification would not be helpful for decision-makers. Achieving their confidence in solutions is of paramount importance before resources can be spent.

The Single Sky legislation clearly supports a partnership approach to development planning that will lead to more efficient investment. The financial tools of the Commission can be directed towards the pre-operational aspects of the strategy. Organisation of the institutional arrangements for an orderly implementation programme also lies in the scope of the European Commission.

In the light of the above, the partnerships which the ATM systems manufacturing industry believe to be essential are those through which Eurocontrol provides the guidance for common specifications for a new architecture of Pan European ATM Systems, that satisfy stakeholders and are proven feasible by the ATM Industry.

With the support of the European Commission, the ATM industry develops the new architectures, and ANSPs, airports and airlines validate such new architectures. They then proceed with the procurement of the correctly designed elements of the new ATM system.

5.3.4.1.2. The industry view on R&D

Industry must have an earnings perspective when it commits funds for product development. The decision factors include cost-benefit analysis and anticipated return on investment.

As a kind of paradox however, Industry strives also for being involved in the early stage of R&D. This is to avoid the multiplication of dead end projects, to promote timely move towards mock-ups and prototypes[57], to focus on viable solutions and to curtail the overambitious approaches. Manufacturers look for a strategy to control risks and accelerate system implementation through R&D action.

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[55] and potentially, maintenance costs if a central organisation is chosen as for ARTAS.
[56] The funding may cover for instance the specification of interfaces and the development of mock-ups to test the data exchanges between those FDPs considered in a joint FDP programme (and also with neighbouring FDPs).
[57] Two thirds of projects did not involve Industry and most of them are paper studies.

Industry is favourable to the idea of European "validation platforms" to validate concepts (or specifications), architecture principles, middleware and standards[58]. Wanting to be involved sooner in the definition of projects and their developments, ATM suppliers require a true partnership with the EC and Eurocontrol[59].

☞ The G2G programme, which is key to the validation of promising ATM concepts[60], must given the highest attention and priority. The programme will contribute also to the development/strengthening of partnership between ANSPs, industry, Eurocontrol and the European Commission.

☞ The participation of Industry is essential to the definition of feasible standards, and their active involvement in EUROCAE WG 59 and WG 61 could be supported financially by the EC.

Through the offices of AECMA, ATM systems manufacturers have also recently subscribed to a Partnership arrangement with Eurocontrol for the European Commission 6th Framework programme. The same manufacturers are part of the Advisory Council for ATM Research in Europe (ACARE) addressing jointly the needs for ATM research well into the future [D13].

Industry asks for "a cultural and managerial change towards leadership and commitment". The ATM industry is ready to invest in the 6th Framework Program (starting in year 2004), provided that an increased competitiveness and a timely financial return can be secured[61].

The following picture taken from [D14] sums up the relationship foreseen by Industry between the stakeholders.

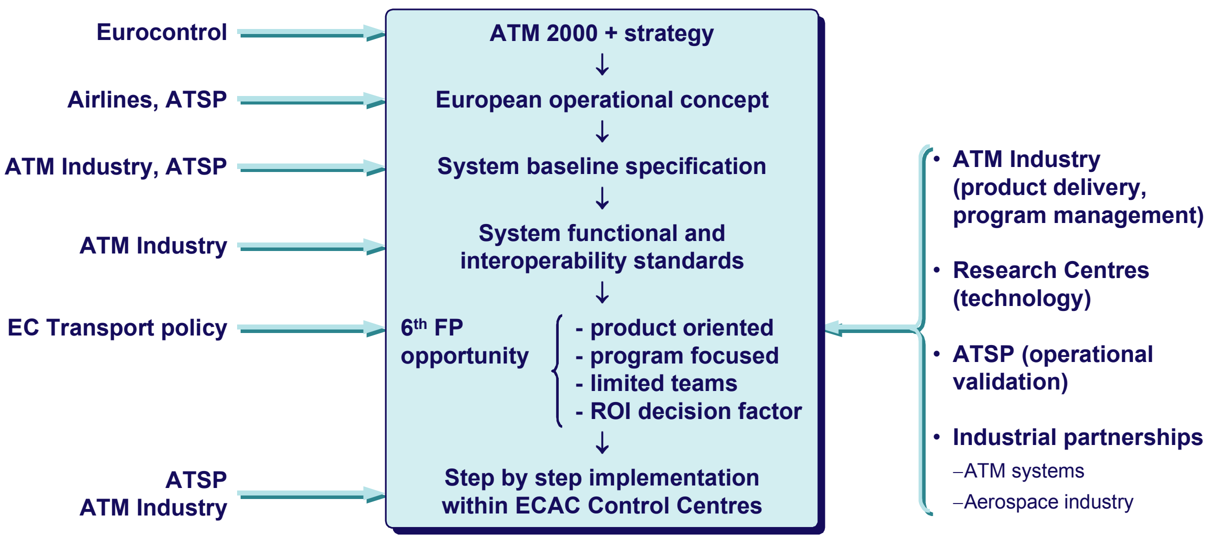

Figure 5.2: Industry view of stakeholders involvement in ATM

A stronger participation of Industry in the 6th FP is in line with the global strategy of the Commission, the successive EC FPs being more and more oriented towards pre-operational validations (in spite of the feeling of industry that the 5th FP gave them not enough place).

58 Industry is less prone however to the notion of "qualification platforms" to check compliance of industrial components against European standards.
59 Muti-partnership developments are already underway in the frame of R&D projects sponsored by the DG TREN such as AVENUE and G2G which involve partnership between Eurocontrol, ANSPs and ATM Industry.
60 e.g. concepts of separation by the pilot will be investigated; G2G will address also the air/ground 4D trajectory integration (this matter is strongly connected with FDP).
61 "The DGTREN 150-200 M€ 6th FP should converge the EC Transport policy and the competitiveness objectives of European Industry"[D14].

☞ “The right solution” is not in the hands of one single party. Industry can really have a more proactive attitude in this partnership and take part in the definition of the strategy if they stop considering themselves only as suppliers.

☞ However, the definition and validation of concepts take always longer than desired. In parallel to pre-operational systems, R&D projects with a medium term return (i.e. 6 or 7 years) will still be necessary in the 6th FP. Therefore, we do not think that the program management of the 6th FP can be given so easily to Industry

5.3.4.2. The question of a central body to control R&D

ATM R&D in Europe is fragmented. The PHARE-X association, which gathers some major R&D units and ATSPs from the core area, supports vigorously the pluralism of its participants but is promoting further co-ordination and harmonisation of ATM R&D in Europe. The association recommends now a central, supported ATM strategy with operational objectives and an agreed body for central direction and control [D12]. Better control & co-ordination of R&D as part of a total cycle is needed.

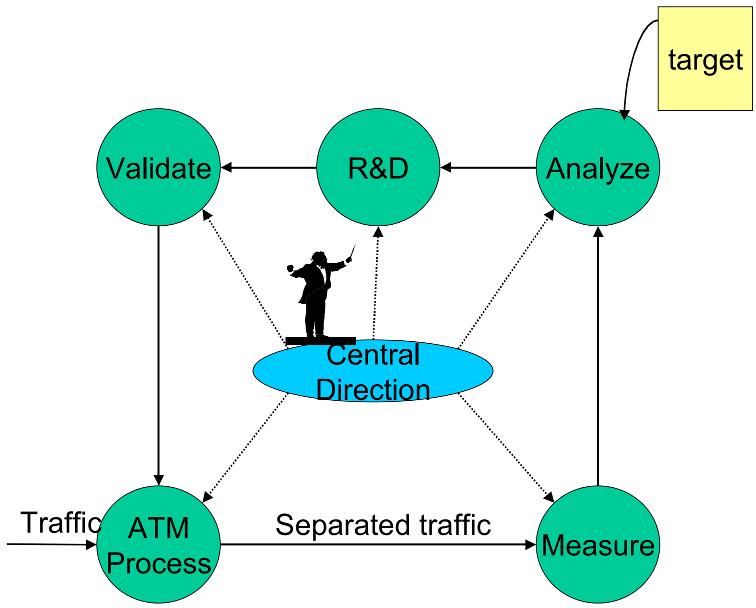

Figure 5.3: A central body in the Deming cycle for R&D

It seems that the recent ACARE initiative which intends to federate the EC, Eurocontrol, ANSPs, Industry is a good basis to define a strategy and priorities in R&D. However it could be a too high level body for effective central direction and control.

5.3.4.3. Intellectual Property Rights

A difficult issue relates to the IP rights for projects developed in a collaborative way. In R&D, the background of one project is the foreground of other ones. It is not so simple to define in a project what is background and foreground (example: if you add source code to existing software).

The example of ARTAS shows that the solution can become inextricable when several stakeholders share IPR. The IPR policy relative to prototypes realised by Eurocontrol is not defined outside ECAC area.

The status of the IPR can block the diffusion of standards (ex: API defined by pieces of source code could be seen as covered by IPR).

Industry has difficulties to find a business case for products developed by Eurocontrol. Inside ECAC, these products are free of charge. Outside ECAC, the situation is not clear.

5.4. Extendibility of the approach

This section addresses the extendibility of the foreseen development and procurement approaches to other collaborative projects, especially those having a more or less direct relationship to the FDP.

First of all, it is worth mentioning that most of the statements and recommendations already made in this report are not restricted to the sole FDP. Decision-making strengthening, performance-driven management, stimulation of partnership and joint procurements between stakeholders, all this has to be understood as applicable to the whole of ATM projects.

Our stakeholders' survey has confirmed that the validation of concepts, the definition of operational requirements, the definition and validation of common infrastructure can only be achieved through a large partnership.

On the other hand, the development of industry products as well as the detailed specification of systems taking account of the local specificity are today treated on a case by case basis safeguarding Industry interests (including IPRs). There is no reason to go against this natural trend.

The ultimate stage of inter-operability would require the specification of common APIs (Application Programming Interface) and common middleware and/or Operating System mechanisms for describing inter-component interactions. This level of specification would enable software modules to be plugged or replaced easily. The related architecture work - initiated by the AVENUE project - will continue in G2G although this is not one of its priorities.

As illustrated by Figure 1.1 in Chapter 1, the issue of interoperability encompasses not only data exchanges between Flight Managers but also exchanges with the other tools (AMAN, DMAN, CWP, surveillance). This means that the definition work to come up at European level with an overall architecture and specification of the components must be pursued[62].

- AMAN, DMAN are too limited in scope and too locally orientated to legitimate a collaborative realisation (note that the equivalent project aiming at common requirements for all the approaches has been stopped at the FAA).
- The Environment management is on the way to find a cost-effective solution with EAD.
- Surveillance has found good solutions with ARTAS.
- MTCD is more a function than a tool. A lot of money has already been spent but tangible results have not yet been obtained and the time has not come to embark on pre-operational developments.

Air/ground Data Link is a domain to which a lot of R&D have been dedicated, often through large collaborative programmes (e.g. AFAS, MAFAS, G2G). Very limited applications have been implemented so far (e.g. departure clearance).

The European project DADI2 is an example of a collaborative project focussing on data link aspects. The project is working on the Open Communication Architecture (OCA) concept, which could allow an ATS centre to collect aircraft-derived information via any air-ground medium with minimum impact on the ATC system on the ground.

The Datalink Information Server (DIS) acts as a gateway to the air-ground media (Mode S Specific Service, ACARS, VHF Datalink Mode 4, ATN subnetworks such as VHF Datalink Mode 2, Mode S and SATCOM) and includes an intelligent database to supply downlinked

[62] e.g. the activities of the Operational Interoperability Task Force from Eurocontrol will lead to an agreed interoperability Concept, a Dictionary of Data to be shared and exchanged and proposals for short-term implementations.

data (DAP) to users (Flight Data Processors, Air Traffic Controllers, MET database,...) through a common interface as illustrated by the following picture:

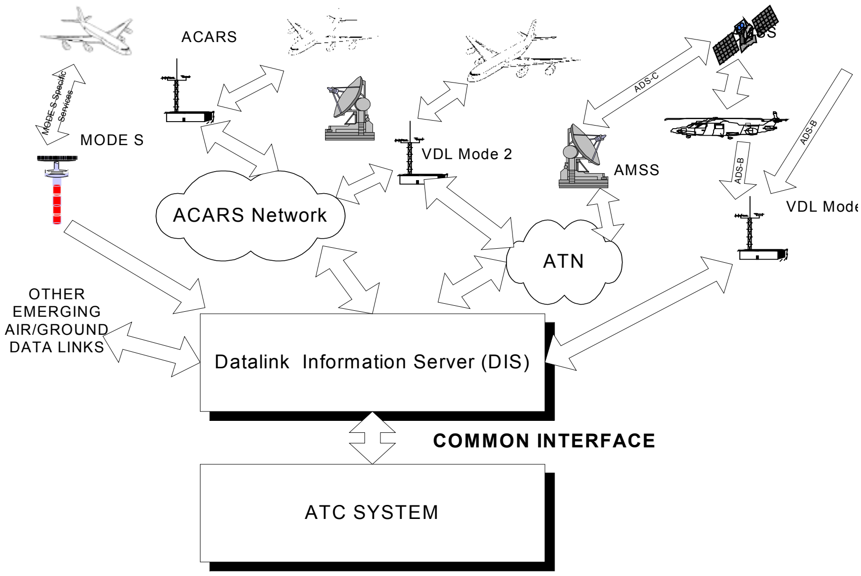

Figure 5.4: An open architecture for D/L

This area deserves a large attention from all stakeholders (Eurocontrol and European Commission have shown an interest in that field) and it is probably a promising way towards more capacity.

Concerning advanced controller tools - such as multisector planning, conflict resolution assistance, approach metering and sequencing, en route manager which would all benefit from D/L exchanges - it is essential to promote the development of prototypes / mock-ups to help in the definition of architecture and interoperability related needs.

Most of those tools - which do not have the same level of maturity at present - will be validated using the G2G platform. This means that the standardisation of corresponding interfaces can only be achieved in the medium term (at least 5 years from now on) given the duration of the project (3 years) and usual lag of standardisation activities (2 years). This is a domain in which the European Commission and Eurocontrol strive today for successful R&D (especially by injecting funds and resources). This effort shall be maintained in the immediate future[63].

[63] For instance, the implementation of multisector planning is not foreseen before years 2009/10.

5.5. Conclusion

The European Commission promotes actively the improvement of European ATM in general, and FDP systems in particular.

The following recommendations should foster further collaboration between ATM partners for a more efficient European ATM system able to cope with the traffic demand of years to come:

- to encourage timely progress by promoting standardisation and interoperability between the existing systems.
- to co-ordinate and optimise the regulatory environment area by giving the Eurocontrol Agency a structural role in the development of implementation rules and standards.
- to look for an overall co-ordination/liaison of the various working groups involved in the ATM architecture definition, ATM architectures standardisation, and ATM systems interoperability (Eurocontrol, Eurocae, CFDSG) in order to ensure technical consistency and avoid overlap or duplication of work.
- to promote interoperability standards leading to reduced development costs and accelerated development life-cycles through EUROCAE WG59 and WG61, with appropriate funding when necessary.
- to endorse CFD initiatives keeping in mind the necessity to find short term solutions and to take into account the requirements of the future controller tools, but being concerned with cost efficiency and the practical needs of the users.
- to promote the culture of performance through the definition of objectives, implementation plans, benchmarking and transparency, not only for operations proficiency but also for cost-effective development, procurement and implementation of interoperable systems.
- to promote collaborative projects done on a voluntary basis involving two or more ATS providers (and Industry suppliers) concerning interoperability and connection to other systems, for example by appropriate funding support; consistency with other projects should be assured by the participation of these stakeholders in the standardisation groups; funding support could be brought to upgrade the systems to be compliant with standards in case of timing problems.
- to continue and promote the partnership with industry suppliers , e.g. the 6th Framework Programme, the development of mock ups, the validation of pre-operational systems, and to invite suppliers to become more pro-active in global strategy definition.
- in the co-ordination of R&D activities to stress integration of Industry projects into the global context and to push for the definition of a central body for management and control, e.g. under the umbrella of the ACARE initiative.
- to push and support those R&D programmes where the validation of common architectures, Data/link and tools for the controllers are pursued in a collaborative way.

Improving performance through partnership could be the summing up of the above recommendations.

The forms of collaboration between stakeholders that we are advocating involve real cultural changes in management practices.

This is a long process where every small step should be encouraged. Bottom up initiatives can fit in with top down decisions.

6. THE EVOLUTION OF FDP SERVICE PROVISION ORGANISATION

6.1. Statement of work

6.1.1. Objectives

The objective of this chapter is to address the policy and regulation issues of FDP service provision. The key issues to be addressed were:

- The assessment of different forms of organisation for providing the service,
- The identification of different service levels and their regulation,
- The feasibility of creating a specific licensing regime for FDP service provision.

6.1.2. Key issues and approach

The first part of this chapter is an introductory discussion to the issue of how to organise FDP service provision. It contrasts “unbundled” service provision (that is the sub-contracting or delegation of part or all of the FDP services to a specialised provider) with the conventional integrated service provision in which the FDP function remains part of the intrinsic ATSP structure. It describes how part or all of the FDP services could be provided by an organisation distinct from the organisation in charge of provided ATC services and discusses the relationship between system architecture options and organisational options.

The second part of this chapter summarises the need for an evolution towards a more efficient and seamless provision of FDP service and the institutional and regulatory constraints that apply to FDP service provision. Recommendations then follow on how the legal and regulatory framework could/should evolve to alleviate such constraints.

The third part of this chapter describes the different organisational set-ups that could be adopted for the pan-European development of enhanced FDP services and makes some recommendations on the approach to be followed.

6.2. Unbundled vs. ATS-integrated Service provision

6.2.1. The concept of “unbundled service provision”

The adequate context for discussing the unbundling of FDP services, is the context of information processing and communications. “Service provision” describes a relationship between a provider and a user, the service provider being the operator of a certain equipment or system which is accessed by the user only through a certain service interface. Depending on the type of service agreement established between the parties, certain services can be made available to some users and denied to other users.

A service provision agreement or business contract consists of:

- An identification of the parties involved,
- a functional description of the service provided at the interface,
- an identification of the point(s) of delivery and the associated protocol(s), giving the technical characterisation of the devices and dialogue scheme needed for requesting and receiving the service(s),
- a service performance commitment including metrics (such as the response time to a service request presented at the interface, the reliability and availability of the service, its integrity, its capacity, its average and peak throughput),
- additional clauses addressing certification, responsibility and accountability (liability) issues.

When operating various ATM-related technical systems, the organisational concept of service provision amounts to putting a given technical system within the scope of responsibility of a certain entity (the system operator).

Other entities may use the functions of the system through a well-defined service interface, without having to install, operate, maintain and replace its own system for fulfilling the same functions as those that can be obtained through the service interface.

The approach of using a system operated by a separate organisation is generally described as an “externalisation” from the standpoint of the provider of the core service.

This term represents, in this context of the FDP service, the notion that the operator of (part of) the FDP system would be organisationally ***external*** to the user of the FDP service that is an individual ACC or an ANS provider.

ATM operators not only co-operate as "like with like;" they also develop support relationships with common third party suppliers of products and services.

An example has been the centralisation of certain ATFM services at the CFMU. Such delegations or outsourcing of services typically reflect economics of scale and scope. This can result in contrasting forms of action and organisation. In such a case, central supply of a specific service will be chosen to save costs and ensure uniformity of performance. In other cases, the availability of competing suppliers will be an argument for unbundling functions that can be provided by a number of firms subject to market discipline.

It is already the case that a number of ancillary information services (such as Met or AIS) can be provided to the end-users as operationally (and contractually) separate from the core ATC service, thus starting a process of service “unbundling”. This approach of using supporting services operated by a separate organisation can also be generally described as an “externalisation” from the standpoint of the core service provider.

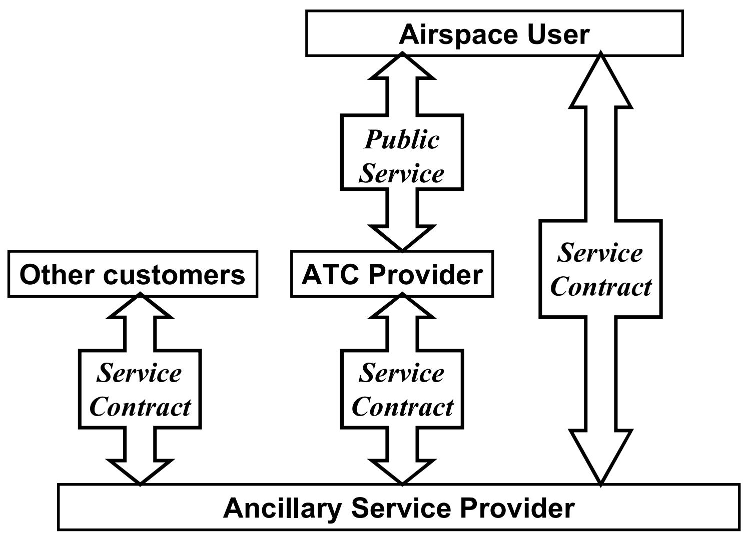

Figure 6.1: Services between users and providers

A “public service” derives from an obligation to be fulfilled by States under international conventions and/or their own national law, while a Service Contract is freely entered into by the contracting parties at their mutual advantage.

As shown in the diagram above, this organisational autonomy from the “core services” of traffic control may raise a number of regulatory questions regarding:

- the necessary relationship that must be maintained between ATC (the “core service”) and the separated service,
- the type of relationship to be established between the end users (i.e. operators of aircraft) and the provider of the separated service,
- the relationship with new potential customers that would be neither the usual end users that fly in the airspace nor the ATC.

The question to be answered by this study is to which degree and according to which modalities the flight data processing activities could lend themselves to the same concept of organisational separation.

6.2.2. The organisation of service provision

One of the main technical difficulties of conceptualising the notion of FDP service provision is the pervasive presence of flight plans and more generally flight data in all ATFM and ATC activities that translates into a large number of ***two-way exchanges*** between different functional sub-systems.

However, this intrinsic complexity of the FDP domain should not prevent us from applying the generic service provision model described in the previous section to part or all of the corresponding activities.

For example, there are a lot of interactions taking place between a Controller Working Position (CWP) and the associated Flight Data Processing System (FDPS), as the controller may collect information and modify various characteristics of the flight through dialogue with the pilot. The CWP can then update through its Human Machine Interface (HMI) some attributes (e.g. the current Flight Level) associated with a flight temporarily placed under his responsibility.

The processing of controller-pilot co-ordinated modifications to the Flight Data can be described with a 3-fold operational model, showing the role of the controller as an intermediate between the pilot and the data processing system on the ground.

As shown in the diagram below, this operational model can be embodied by two different organisational models, depending on whether the ATS Provider is also considered as the operator of the FDP system or not:

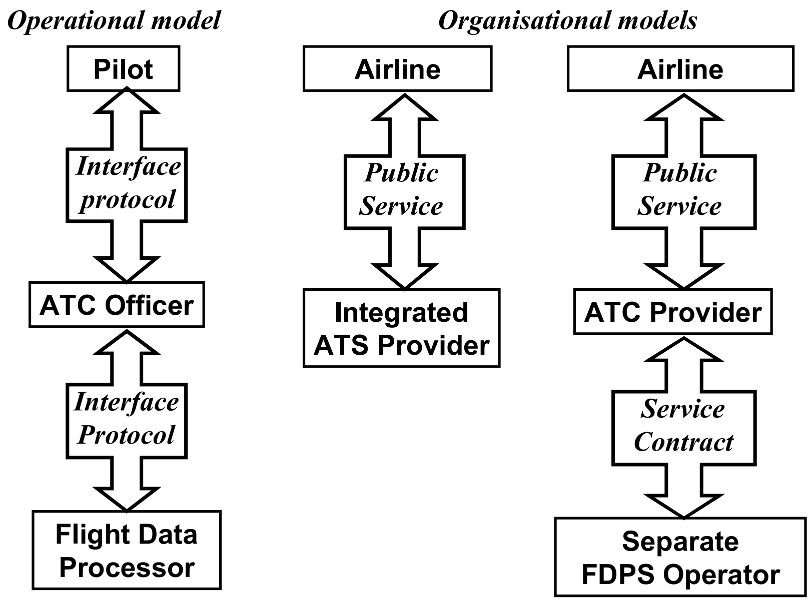

Figure 6.2: Operational and organisational models

This example shows that the contractual relationship within the organisational structure should reflect some (but not necessarily all) of the articulations that exist in the operational model and the underlying system architecture.

Here, it is only the basic service of updating, storing and redistributing the flight data at the level of the Controller Working Position that is described.

Obviously, any unbundling of services requires a stricter definition of the corresponding system interfaces and operation rules.

This stricter approach to system modularity and integration is considered as good system engineering practice. Thus, the development of a new generation of FDPS should be based on a clear definition of the different functional components of the whole system and their interactions and service interfaces.

That would make it easier to take a more flexible and modular approach to FDP service provision as well. Even if a bundled service provision approach is maintained, future FDP systems will be less monolithic than the current ones, and this is a good thing.

As it is always possible (and indeed recommended by modern software engineering practices) to discuss system architecture in terms of service provision interfaces and interaction protocols at these interfaces, we can formalise the FDP system architecture in this way, even if the organisational model retained cannot go so far into the breakdown of FDP activities into elementary services.

In terms of technical architecture, the remote provision of a FDP service is already widespread for ATC activities at TMA level: CWPs serving a small TMA may be connected to a distant FDP (e.g. located in an En Route ACC). However, the whole system remains under the control of a single organisation.

Therefore we can describe globally as “FDP service provision” the complex combination of all the ATM interactions creating, using and modifying the flight plans and any tactically appended additional flight data, and then refine the scope of our analysis on the basis of current organisational and operational practices.

In the next section, we discuss in more detail the interdependencies between the architectural scenarios and the service unbundling approach. Then we describe and discuss current practices in the functional area of FDP.

6.2.3. Organisational scenarios and system architectures

We have identified 3 main system architectures for structuring technically and operationally the provision of the future FDP services:

- A baseline consisting of independent and loosely co-ordinated FDPS, each of them being associated with an ACC, with remote APP and TWR terminals possibly connected to the FDPS. This baseline corresponds more or less to the current structure of both inter-FIR and intra-FIR FDP operations, with only interface interoperability between adjacent systems.
- A central FDP model, consisting of a single FDPS for the whole of Europe, serving all of the ACC’s as well as local users (TMA and TWR), with en-route and terminal specific tools still being procured and operated on a local basis.
- A closely co-ordinated network of FDPSs, consisting of a number of tightly coupled FDPSs, meeting strict performance requirements (and not only interface compatibility requirements) each of them serving one or more ACC’s, plus, optionally, a central data redistribution facility (the “data warehouse”).

On the organisational side of externalisation, we have three possibilities:

- The ATS provider is also the FDP service provider (integrated service provider),
- The FDP service provider is not the ATS provider but there is only one FDP provider per ATS provider,

- One FDP service provider for several ATS providers.

The following table presents a summary assessment of the degrees of compatibility of the different possible associations between organisational scenarios and system architectures:

Architecture option vs. Externalisation strategies	Baseline	Central FDP	Network of FDPS (+ data warehouse)
Integrated ATS provider	YES (current situation)	NO (only one FDP provider)	YES for Different ACC of the same ATSP; NO if the ACC depends on different ATSP; NO for the data warehouse
One FDP SP for one ATS Provider	YES	NO	YES
One FDP SP for several ATS providers	YES, if the common global service can really be adapted to every individual FDP architecture	YES	YES, if the common global service can really be adapted to every individual FDP architecture. May be limited to the services offered by the data warehouse

The bottom left case is a qualified YES, because adapting a global service provision to the many idiosyncrasies of locally designed and operated FDPS may be too difficult.

For the same reason, it is possible to imagine a single FDP service provider running a whole network of FDPS serving different ATS providers, but adaptations to local conditions may be difficult to manage beyond the functional scope of the data warehouse, unless detailed standards are put in place beforehand.

The issue we are discussing here is not exactly the same as the technical issue of installing one FDP system in each ACC versus having an FDP system capable of serving several ACC: a multi-ACC ATS provider may put in place a multi-ACC FDPS without going for externalisation.

Alternatively, the same multi-ACC ATS provider could decide to unbundle the provision of FDP service on a per ACC basis, i.e. maintaining a one-FDPS-per-ACC model (e.g. because of dependability concerns).

The 2 issues are however related in the sense that an increase in the technical modularity and flexibility of the whole system would favour the development of a variety of organisational solutions.

6.2.4. Current system operation and service provision practices

6.2.4.1. Pre-tactical FDP service provision

The European-wide planning of traffic flows and the associated Initial Flight Plan System (IFPS) processing facility are managed by Eurocontrol (but many national centres supplement the IFPS function to some degree).

The role of Eurocontrol in ATFM activities is explicitly defined in the revised Convention of September 1997 (cf. Article 2.1 (e) of that Convention).

The FDP service provision associated with ATFM is therefore split into two phases:

- in the pre-tactical phase, the ATFM part of the Flight Planning activities is centrally co-ordinated by the CFMU, and the resulting Flight Plans are distributed to the relevant ATC systems in the departure airports and initial area control centres,
- in the tactical phase, the Flight Plans are activated and supplemented by additional data (available only within minutes of the departure such as the SSR code) and the FDP system in the

first control centre manages locally the evolution of the Flight Plan and its transfer to the FDP system of the next centre (and also to the IFPS, the TWR system and the military systems) as the aircraft moves from one area of responsibility to the next one.

The initial processing of Flight Plans at the level of the CFMU is managed as a public service provided by the Eurocontrol Agency to the ATS operators of its member states (and more widely to ECAC States).

The “customers” of the CFMU are the different national centres, but there is no real contractual framework here, so the very notions of “provider” and “customer” would be misleading. All the more so as the “provider” (the CFMU) is dependent on the capacity information provided by its “customers”.

A number of recommendations have been made by Sofréavia and its partners (WCP, DFS, UK CAA) in a previous study for DG TREN (ASM Regulation) for improving the mutual perception of the CFMU and ACC’s as provider and customers of a central AFTM service and putting in place some regulation of the ATFM service provision. These issues are therefore considered to be outside the scope of this study.

Here our focus will be on the tactical phase, that is the collection, verification, computation, integration, update, storage and distribution of flight data exchanged in respect of flights in progress.

6.2.4.2. National ATSP and their arrangements

Presently, ATM operations in Europe are managed by many different ATS providers whose respective zones of responsibility are almost everywhere aligned on national boundaries. Each national provider operates one or more Area Control Centres, each of them including a Flight Data Processing system and having telephone and data connections to adjacent centres in other countries.

In the current system, every ATS provider supports through its investment and operational budgets, the development, operation and maintenance of its own FDP system and its own part of the inter-centre FDP co-ordination costs.

Since FDP systems are at the heart of the ATC activity, and have many links to other functions and external systems, the notion of “FDP service provision” is probably not easily discernible in the current external budgetary structure of the ATS providers: for example the cost breakdown structure used at the level of the CRCO identifies only ATM and CNS as major budgetary items and ATM is further refined into ATS, ATFM and ASM.

However, the major costs entailed in developing and maintaining/evolving FDP systems are certainly documented well enough in the internal budgetary structure of the ATSP, although it is unlikely that a more detailed breakdown (e.g. distinguishing between the Flight Manager and the Controller tools) would be readily available on a homogeneous base for the entire ATSP.

Also, from the standpoint of current practice in ACC organisation and management, the concept of “FDP service provision” is a bit of an abstraction, as certain structures (e.g. operation and maintenance team) may be intimately shared with other functional systems.

For example, the supervision and maintenance of the different ACC computer systems for surveillance processing, flight data processing, controller working positions, meteo and aeronautical information processing, etc. may be partially or fully integrated.

To remain at a level of abstraction which is suitable for our analysis, we can define the provision of the Flight Manager (FM) service as the ability to receive, update and distribute, internally and externally the information describing:

a) the nominal intentions of the aircraft flying into a given area of responsibility
b) trajectory interpolations produced by various technical means,
c) a number of technical parameters attached to the flight at various stages of its lifecycle.

This FM Service is integrated with a number of other functional services to produce the global FDP function.

The quality of the FM service or of the other (sub-)services contributing to the global FDP service (correlation, trajectory prediction etc.) may be characterised by parameters such as:

- Its capacity (maximum number of flights that may be simultaneously managed),
- Its integrity (probability that an error in flight data does not go undetected),
- Its availability (probability of service outage over a certain period of time),
- Its timeliness (maximum delay between a flight data change and the corresponding update in the flight data base),
- Its space-time accuracy (precision of the associated trajectory prediction).

The current dominant model is as follows:

- The ATS providers individually procure their FDP system from the industry (including a service contract for hardware and software maintenance) with a significant involvement of their own technical personnel in the technical specification of the system
- They make co-operative institutional (non-commercial) arrangements with adjacent ATS providers to solve communication interface issues and co-ordination problems in relation to the FM service,
- They run their system in an integrated way from the standpoint of configuration management and maintenance, although day-to-day operation and maintenance services may be contracted out to the facility management service industry with the system remaining located in the premises of the ATSP
- They provide to themselves an integrated FDP service by associating their FDP system with various human resources[64]
- They provide by mutual agreement an FDP service to their neighbours on the basis of non-commercial reciprocity, without explicit commitment in respect of the quality of the provided service (best effort from all parties, with little or no stated performance targets).

The following diagram summarises the various external relationships and internal organisational links that have to be established to produce an FDP service at the level of an ATS provider in the current organisational model:

[64] It should be noted here that the activity of ATC controllers consisting of updating the flight plans through their HMI is an integral part of the FDP service provision in a total system approach. We consider here only the configuration management and maintenance support to the operation of the FDP -- seen as a technical service for data storage, processing and interchange -- and auxiliary services obtained from various external service providers (telecom service providers).

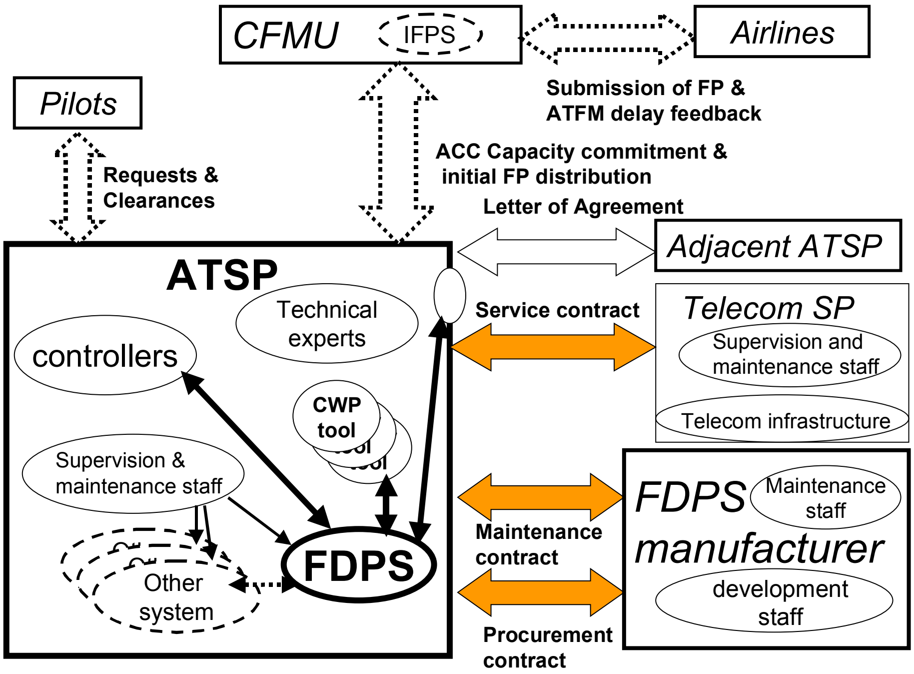

Figure 6.3: the ATS provider in the current organisational model

In the future, new or additional contractual agreements may appear: for example, if the ATSP stops operating its own AIS and signs a contract with an external entity managing the EAD or other services, then a service contract (similar to the one existing with the telecom SP shown on the above diagram) should be established.

6.2.4.3. The multi-national Maastricht Control Centre

The Maastricht Upper Airspace Control Centre (MUACC), operated by the Eurocontrol Agency on behalf of the 4 participating States (Benelux and Germany), is supported by some equipment operated by these countries located outside its scope of ATC responsibility. In addition to MUACC's own equipment (ODS CWP, MADAP FDPS) a number of national facilities are made operationally available to the MUACC free of charge for joint use.

These facilities are listed at Annex II of the "Agreement relating to the provision and operation of air traffic services and facilities by Eurocontrol at the Maastricht area control centre".. That annex is titled "Special provisions concerning national facilities and services to be made available to the Organisation by the National Contracting Parties".

That list includes, for example, the services of the Frankfurt AFTN switch and the German ZKFD (strip-printing facility) for transmitting ACT messages, or the provision of weather information from the Zaventem Met Office.

However, it should be noted that the associated service provision model is defined quite loosely and does not really qualify as an instantiation of the service unbundling approach described in section 6.2.

6.2.5. The FDP service outsourcing model

The main organisational difference with current practices described in section 6.2.4 is that the operator of the FDP system is no longer the ATSP itself but another party, either a specialised operator (public or private) or another ATSP. Since our aim is to provide a description of functional roles and not of real actors, the reader should keep in mind that different functional roles (represented in our diagram by different rectangular boxes) may in fact be fulfilled by the same organisation.

Since the FDP service is crucial for ATC, the outsourcer would expect a stronger commitment from the outsourcee than what is currently done. Creating a sufficient level of confidence in the outsourcing approach would require a more precise definition of responsibilities and a stronger performance commitment than the current “best effort” policy.

Therefore, outsourcing the FDP service requires a clear definition of the interfaces and a contractual description of the service provided. Technically, the description of an FDP service contract should consist of a description of the various functional services provided, and for every service:

- A description of the data exchange and interaction protocols to be used at the interface,
- A specification of Quality of Service (frequently denoted as non-functional requirements).

The following diagram describes the contractual model for outsourcing the FDP (or for that matter any other) service.

A procurement contract between an FDPS manufacturer and the FDP service provider still exists; but it is not shown on the above diagram as it is no longer within the direct scope of visibility of the ATSP (which does not mean that the ATSP has no say in the specification and selection of the FDPS manufacturer by the FDP Service Provider).

As explained before, the complete FDP service is produced through the activity of a number of functional modules integrated around the basic FM service.

Depending on how many of these modules are externalised, the service contract may spell out performance commitments reflecting the quality expected from the whole FDP service or only from this or that more elementary contributing service, especially the FM service, which can be seen as the most realistic starting point for the unbundling of the FDP service.

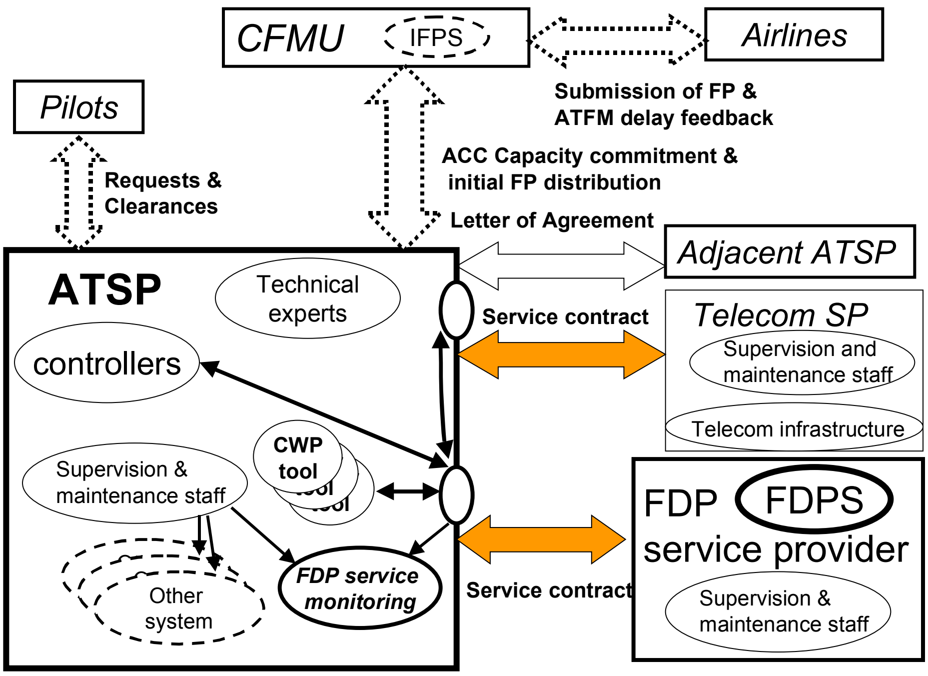

Figure 6.4: the ATS provider in an organisational model with outsourcing

6.3. FDP Service Provision Issues

6.3.1. The impact of new operational needs

The need for an evolution of FDP service provision derives from the following needs:

- The permanent need to increase the capacity and responsiveness of the whole ATM system under the growing pressure from airspace users to reduce the operational fragmentation of the European airspace
- The need for an expanded distribution of tactical flight data so as to allow new tools to be employed to improve ATC performance,
- Following the events of the 11th of September 2001, the emerging need for an extensive review of the security policy regarding the distribution of ATM data.

The need for ATM "de-fragmentation" can be interpreted at the level of the FDP service as a need to develop a global and completely consistent view of all flight data, with any tactical updates being accurately recorded and quickly distributed downstream. Today, various organisational and technical factors lead to the frequent appearance of divergences and inconsistencies between the Initial Flight Plans and the local copies managed by the different ATS providers.

This translates into a need for an improved definition of the distribution service, with a common service interface and standardised performance commitments applicable everywhere in Europe.

The need for an expanded distribution of tactical flight data means that the current approach of transmitting a Flight Plan to the next ACC 5 to 10 minutes before the aircraft is transferred is no longer sufficient.

Any ACC should be able to get a complete picture of the upstream traffic in all adjacent ACCs so as to assess 10 to 30 minutes in advance the likelihood of future conflicts emerging in its area of responsibility and ask for prophylactic measures to be taken by the upstream controllers.

The area of interest (cf 1.4.4) of the ATS providers needs to be much wider than before.

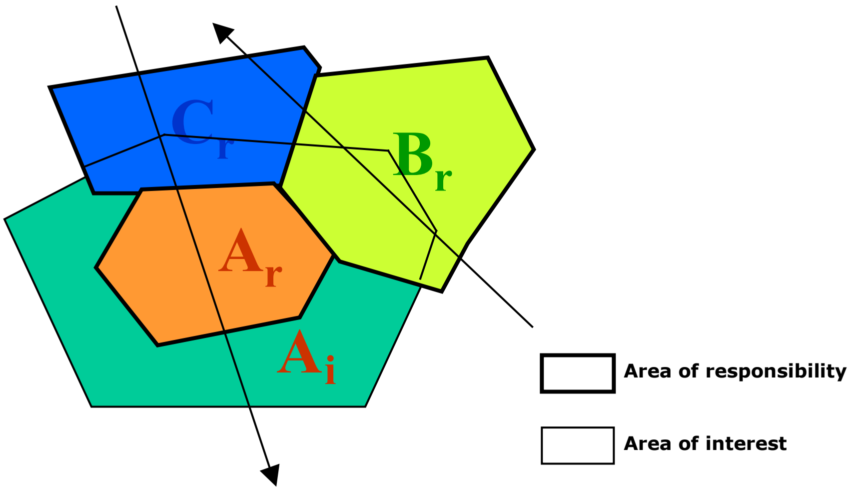

Figure 6.5: Areas of responsibility and of interest

On this diagram, ATS provider A needs to get an FDP service covering the areas of responsibility of ATS providers B, and C: every modification (e.g. through ATC interactions) impacting the Trajectory Forecast of a flight located in the area of interest of A and bound to arrive soon in the area of responsibility of A has to be transmitted to A. A must receive timely data with an adequately homogeneous level of precision: if B, and C provide their data at different standards of delay and accuracy, they cannot be of much use for A to determine a correct picture of its future traffic situation.

Future FDP systems are expected to be able to produce and distribute sophisticated 4D trajectory predictions. The emergence of extensive Areas of Interest implies that common performance requirements regarding both the accuracy of flight data and their transmission delays should be enforced across all the areas of responsibility, which calls for the establishment of common performance standards for the Flight Data Elaboration and Distribution Services.

An additional requirement here is to have also homogeneity of performance for the production and distribution of the Environment and Surveillance data, as they are both necessary for a good quality of the trajectory prediction. If Environment and Surveillance data are not produced and distributed in compliance with a common performance standard, then the “elaboration” service won’t work very well.

Last but not least, the need for a tighter security of ATM data exchange can be interpreted at the level of the FDP service as a need to include user authentication and data integrity and confidentiality protection functionality into the definition of the enhanced FDP services.

6.3.2. National security constraints

Control of national airspace remains politically sensitive because of national security concerns. Even in a multi-national ACC like Maastricht that has been in operation for a generation, ATC is still very much organised along the lines of internal national boundaries: Dutch sectors controlled by Dutch controllers, German sectors controlled by German controllers etc. CNS services to Maastricht UACC are also provided by the national infrastructures.

The envisaged evolution of ATS provision towards more trans-national flexibility may raise national security concerns in three areas:

1) Dependence of modern economies on civil air transport makes safety and security of air navigation a vital interest. Few countries in Europe would accept the entire transfer of their ability to provide ANS, and especially ATC, to sites located in other countries. Transferring a FDD service to some extra-national site would probably be acceptable on the basis of the IFPS precedent. However, transferring completely an AI or even an FM service to a non-national provider would certainly be a source of concern. This could lead States to impose restrictions in the terms and conditions of FDP service licenses, such as a requirement to operate at least one system on the national territory and to employ national personnel to run it, so as to maintain a national base of operation for what is perceived as a critical capability. That facility could serve as a national fallback system at times of international crisis. The risk of not providing redundancy should not be dismissed lightly. The CFMU is located between the close-by Zaventem airport and the NATO Headquarters, both plausible targets of terrorist attacks without mentioning the CFMU itself. Having the CFMU damaged would significantly constrain European airspace until repairs or back-up arrangements could be implemented).

2) There are a number of countries in Europe where ATS services are organised with a high level of integration between civil and military activities (this is in particular the case in Germany and in Scandinavia). This may lead national authorities to set specific security requirements bearing on personnel having to deal with militarily sensitive matters (e. g. the tactical processing of military transport flight plans) such as obtaining a national security clearance as part of their licensing process. In any case, in the context of the overall review of aviation security undertaken at the initiative of the 33rd Conference of ICAO (that took place in Montreal in September 2001), it is likely that tighter security screening procedures for all ATM personnel will be implemented in the near future by all States, independently of the specific issue of joint civil-military operations.

3) The management of tactical flight data related to State aircraft may also be a sensitive issue; however, the twin notions of area of responsibility and area of interest that we have introduced constitute a sound basis for dealing with that matter:

a) if a State aircraft coming from the area of responsibility of an ATS provider operating in State A has to go through the area of responsibility of an ATS provider operating in State B, then that State aircraft will have to obtain a diplomatic clearance to enter State B (unless a bilateral treaty or another permanent institutional arrangement allows State aircraft from both States to enter each other airspace) meaning that ATSP B should receive advance notice of the arrival of that aircraft into its area of responsibility; therefore the transfer of flight data concerning that aircraft to the ATSP in State B should not be a problem.

b) if a State aircraft navigating within the area of responsibility of State A without any intention of entering the airspace of state B, then its flight data may be filtered out from the data flow passed from A to B without reducing the operational capability of ATSP B to conduct its activities based on its area of interest; filtering out those traffic flows in the area of interest of B that have no relevance to its area of responsibility could be routine practice even for non-State aircraft.

6.3.3. ATM and FDP service breakdown

6.3.3.1. ATM Service breakdown

The usual functional breakdown of ATM Services is as follows:

- Airspace Management Services (ASM)
- Air Traffic Flow Management Services (ATFM)
- Air Traffic Services (ATS)
- Communication, Navigation and Surveillance Services (CNS)
- Ancillary Information Services: Aeronautical Information Service (AIS) and Meteorology (MET)
- Emergency Services
- Search and Rescue (SAR)

The last 5 items taken together (ATS, CNS, AIS-MET, Emergency, SAR) are also denoted as Air Navigation Services (ANS).

However, there is no firmly established terminology, and the reader should be aware that a given expression may mean different things in different contexts. For example, sometimes, the CNS equipment and services that are standardised at ICAO Annex 10 are named « ANS services » or « ANS Infrastructure services ».

Depending on the ICAO classes of Airspace, ATS may consist only of Advisory Services (Flight Information Services, Alerting/Control Services) which is the case for classes E (for VFR), F and G, or may include also Air Traffic Control (ATC) Services for the other classes: A, B, C, D and E (for IFR).

ATC Services are frequently denoted as « Core Services » by contrast with ancillary information services (AIS and MET), CNS services and merely advisory services.

The following diagram summarises the most usual breakdown of ATM services:

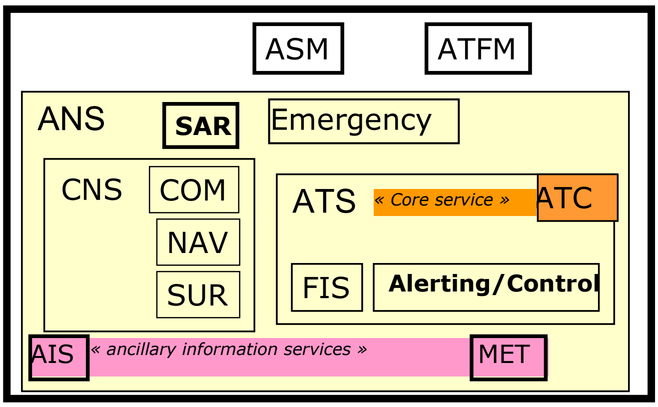

Figure 6.6: ATM service breakdown

It should be noted that the FDP services are identified nowhere in this list of services. Considering their strong links with ATS, especially in airspace where ATC services are provided, they may be considered either as being part of the « Core Services » or as a sort of infrastructure service within ATS[65].

6.3.3.2. Proposed breakdown of FDP services

A key question is how far FDP services could be joined to other non-core services rather than being considered as an ingredient of the core ATC service.

In the introduction (§1.4) we define the FDP service provision as "the provision of ATC flight manager service access points (ATC/FM SAPs) to any client in the ATM field, enabling this client to submit requests for creating, retrieving and processing flight data, according to an agreed user profile." We recall the main function of the Flight Manager and its relations with its environment.

Taking into account the decomposition of the Flight Manager function given in §1.4.3, we can now go one step further and consider in this service provision two responsibilities.

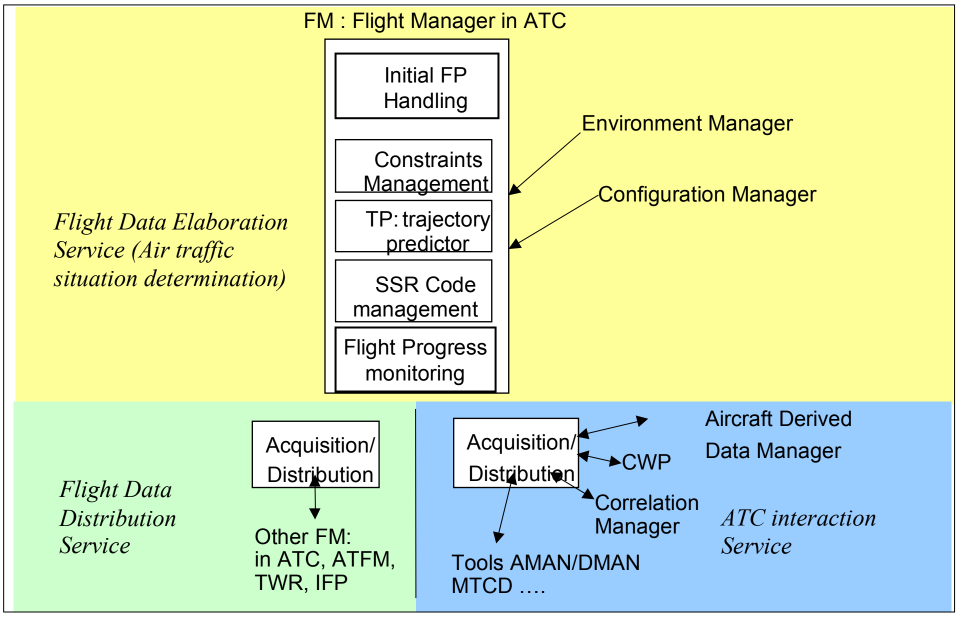

Figure 6.7: Service provision of Flight Data

The first one is relative to the elaboration of data giving warranty on the quality of the data, which is an essential part of the Flight Manager (*Flight Data Elaboration Service*).

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[65] In the NATS En Route Licence (NERL) a slightly different distinction is made between the « Core Services », that is the ATC Services and « Specified Services ». These specified services consist of:

- Communications, including emergency features (refined into Aeronautical Messaging network, ATC Operational Telephone Network, Emergency Fixing Facility, Emergency Frequency Facility)
- Navigation,
- Surveillance,
- AIS,
- UK Met Information,
- Advisory Services (UK Flight Information, North Sea Helicopter Information Services, Nuclear and Chemical Accident Services)

This relatively more detailed list of services consists of CNS, AIS-MET and Advisory Services but again FDP services do not appear and are to be considered as belonging to the Core Services.

The second one is the distribution of data, according to the user profile. The users can be other FM's (in ATC, CFMU, Airlines…) but also any ATM component requiring Flight Data (CWP, surveillance, MTCD…). It is why we consider:

- the Flight Data distribution between FM's that we call the *FD Distribution Service,*
- the Flight Data distribution between an FM and other tools that we call the *ATC Interaction Service*.

These different services correspond to different types and levels of commitment to be made by the provider side towards the user side.

a) For a pure "distribution" service, the only responsibility would be for timely distribution of what is received as a result of ATC interactions and/or trajectory prediction computation activities according to the user's profile defining which information has to be sent, when and how.

Therefore, the Service Level Agreement to be established between the provider and user of the service would contain provisions about the performance of the service only in terms of data transmission:

- the type of data to be transmitted, the conditions of sending,
- the capacity and throughput, the integrity (expressed as a residual error rate) of the data transmitted, the availability and reliability of the service, and its responsiveness in propagating an update.

Several levels of service can be defined. For example, we can consider the services corresponding to the current exchange of ICAO FPL, or OLDI messages. But the needs relative to a better consistency between systems as well as the needs of the new controller tools or data link will require a more advanced distribution service level for the distribution of 4D trajectory data (see below).

The level of service given to a client being one's area of authority could be different to the level of service given in one's area of authority. It is why we made a distinction between distribution of FD between FM's and between a FM and local tools.

b) For the *FD Elaboration Service (Air Traffic Situation Determination)*, the Service Level Agreement would include provisions about the performance in terms of 4D accuracy of the trajectory.

The responsibility of a FM service provider (providing FDP services) would be to guarantee a certain level of performance in respect of both the distribution activity (definition of the data that are distributed, conditions of their distribution, quality of the distribution) and the elaboration activity (quality of these data).

6.3.3.3. Separation of FDP services

In line with the issue recalled in 1.7.3, we can ask ourselves if it is possible to externalise some parts of the FM in order to "unbundle" ATC services while assuring the production and distribution of European-wide consistent Flight Data.

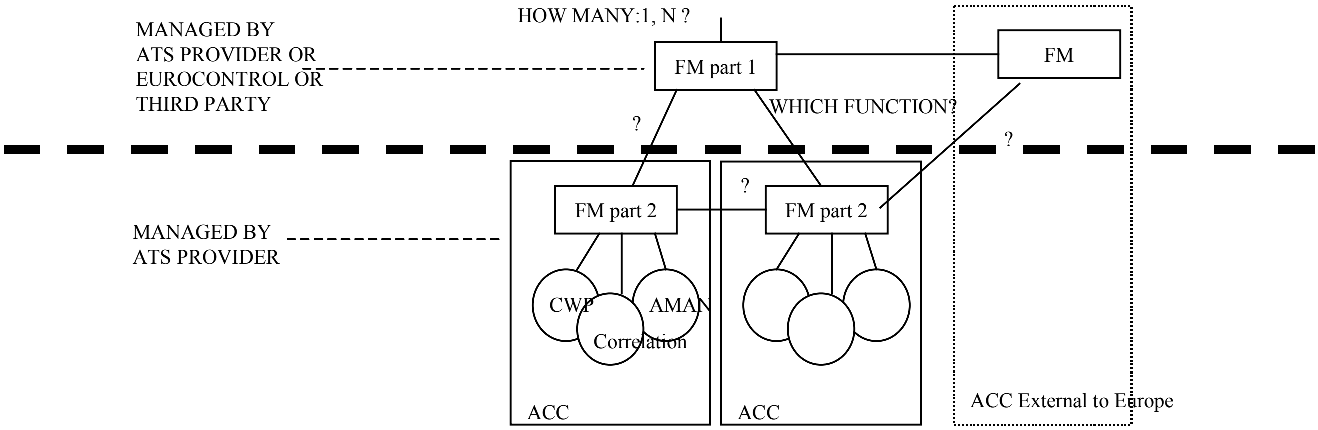

Figure 6.8: Separation of FM services

Would it be possible to separate the Flight Data Distribution Service or the Flight Data Elaboration Service from the rest of FDP service?

In AIS, data are distributed in one way direction, whereas the exchanges of Flight Data between the FM and its clients have two ways direction and are much more numerous and intricate, in particular considering the strong coupling

We think that the unbundling of FDP services could be investigated in three directions:

- **Elaboration/determination of the air traffic situation**

  In this case, the elaboration of the air traffic situation is externalised.

  One or several systems and providers could deliver the service and would not be necessarily dedicated to a single specific ATSP or ACC.

  If several systems co-exist, exchanges could be done when necessary between Air Traffic Situation Elaboration managers to provide to the clients the information relative to their areas of interest (as it can be done between ARTAS servers when the area of authority – cf 1.4.4 - of one unit does not cover the area requested by the client). These exchanges would also ensure the consistency of data.

  Local proxies (front end) would be in charge of the distribution of data inside the ACC (see scenario 2).

  As already seen in chapter 2, the stakeholders reject today the two possible solutions (centralised or distributed).66 Because of national sensitivities, operational dependencies to surveillance and environment services, and the higher level of commitment (i.e. on the accuracy of the trajectory forecast) and from an organisational standpoint, this externalisation can only be considered in a long-term evolution.

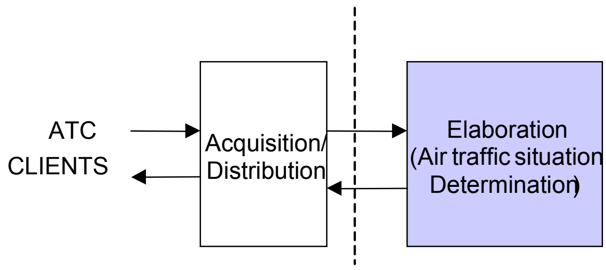

Figure 6.9: externalisation of the FD Elaboration Service

[66] This architecture seems also to be that of the NERC but a grouping of the two services (elaboration and distribution) seems to be investigated now.

- **FD Distribution (between FM)**

  Whereas the ATC interaction service does not seem easily externalised due to the numerous and intricate exchanges between the elaboration function and CWP and other ATC tools, we think that an idea that could be successful is the externalisation of the FD Distribution.

  The distribution of FD would consider the exchanges with the other FM's, that are external to the area of responsibility of the ATSU.

  The level of responsibility committed to here would be similar to what is foreseen in the EAD organisational set-up as described in the preceding chapter, whereby the EAD company takes responsibility for the distribution of the data but the responsibility for AIS data correctness remains with the national AIS entities.

  On the basis of that analogy, it would be arguable to separate the Flight Data Distribution Service from the rest of FDP service and make it a new FDP-related ancillary service.

  The responsibility/liability of the Distribution Service Provider would be limited to the relevance, availability and timeliness of the data transmission according to the user's profile (and would have no responsibility/liability regarding the correctness and accuracy of their content).

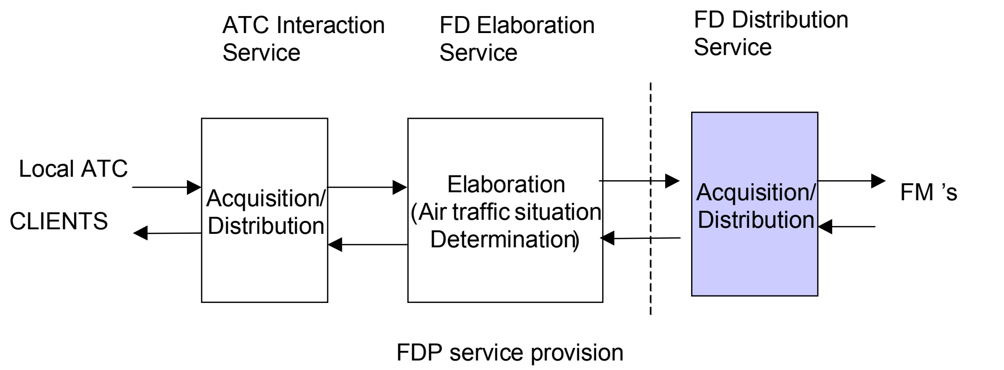

Figure 6.10: Externalisation of the FD Distribution service

Further investigation is necessary. In particular, to check if it corresponds to a real business case.

- **Central FD distribution for non ATC users**

  A special case of FD distribution that is worth to be considered is the distribution of ECAC-wide FD to non ATC users through a central data server or data warehouse as proposed in our convergent scenario (cf 2.6).

  From this point of view, the FD are consolidated and made available in a central point like AIS information in EAD. Being not an integral part of the FM, this service could be considered as an ancillary service for non ATC users as MET or AIS are ancillary services for ATC users.

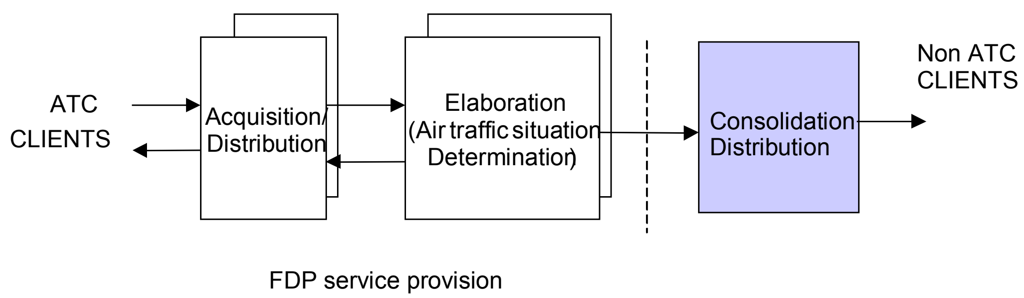

Figure 6.11: Distribution of FD to non ATC clients

The stakeholders could accept the externalisation of such service in a near future.

It is now possible to ascribe the different segments of the functional breakdown of FDP services between Core and non-Core services.

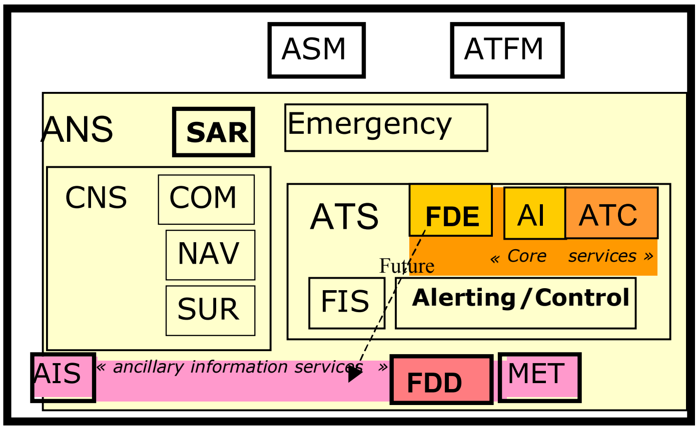

Figure 6.12: Possible future identification of FDP services (FDD, FDE, AI)

We can therefore propose the following recommendation for opening up the field of FDP services to both technical and organisational innovation:

☞ Introduce into the ATM regulatory framework a distinction between FD distribution and FD elaboration services and consider that FD elaboration and FD distribution could evolve from core services to ancillary services.

6.3.4. Liability issues

6.3.4.1. Contractual vs. non-contractual liability

In the area of service provision, 2 types of liability co-exist:

- Contractual liability is the result of a negotiation leading to a contract between the service provider and its client(s) made subject to governing national or European law. Contractual liability can be covered by the private insurance market.
- Non-contractual liability is associated with the consequential damages to any other party (not only its clients) that may be caused by the activity of the service provider. So far liability in this field is governed by "tort" law. Absent an international regime in this area, the law of the country which has the most genuine link with the accident and the damage caused by the accident will govern tort claims.

European Directive 85/374/EEC sets a common regime of non-contractual liability for damages (especially repetitive damages) caused by defective products (e.g. a car model that would cause accidents) but no equivalent framework exists for services, which leaves a lot of room open for interpretation regarding the distinction between a product and a service.

All “movables” are addressed by that directive (including computer software and electricity.) As a number of ATS services can be argued to be embodied in products (e.g. the provision of AIS charts, or the production of paper strips derived from flight plans), that Directive has a certain relevance to our study.

However, that directive applies only to products *“of a type ordinarily intended for private use or consumption”* and if “*used by the injured person mainly for his own private use or consumption”*. In our context, any service-product of a type represented by the provider for use by private pilots in General Aviation would qualify.

The burden of proof is set on the claimant to demonstrate the defect, and, most important in our context, the producer is not deemed to be liable if he can demonstrate that *“the defect is* *due to compliance with mandatory regulations issued by a public authorities" (Article 7 (d) of the Directive)*.

In all cases, the very nature of ATM services as potential contributory causes of air transport accidents makes non-contractual liability an important economic and regulatory issue, and in the rest of this section, we discuss only non-contractual liability issues.

6.3.4.2. Liability assurance

National legislation makes it mandatory for any commercial air transport carriers to demonstrate adequate insurance coverage to be granted an operation licence.

In practice (cf. "The Aviation and Space Insurance Market", August 2000, a survey paper by D. Hart, Ph. Tippin and J. Widdows published on the Internet by a Working Party of the Institute of Actuaries) the main occidental Commercial Air Transport operators carry a hull loss and liability insurance in the range from 1 to 2.5 billion USD. The cost of that insurance varies in a range from 0.12 to 0.30 % of the value of the aircraft per year. Historically, the cost of CAT insurance is increasing for 2 reasons:

- the use of ever bigger aircraft,
- the cost of compensation to victims of accident and other eligible parties goes up.

The case of ATS liability insurance is a rather new field.

As a matter of economic comparison, we can only try to estimate an upper bound of the potential liability exposure for an ATC service provider on the base of a mid-air collision between 2 large airliners taking place in its controlled airspace (supposedly caused by faulty ATC instructions), and producing additional fall-out damages over a dense urban area.

The insurance to be carried for covering such an event would be in the order of twice the insurance coverage carried by an airline, that is an amount in the range from 2 to 5 billions USD. The yearly cost of that type of insurance might be significantly lower than twice the cost of airline insurance because the occurrence of mid-air collisions is significantly lower than the occurrence of single aircraft accidents.

The exposure to liability of the Core Service provider can also be considered as an upper bound for assessing the liability coverage needed for a non-core service provider, as negligence from a non-core service provider might be recognised as a contributing factor to an Air Transport accident, but proportionately much less than the Core Service provider and the airline.

For a provider of aeronautical information the situation of maximum exposure to liability is for General Aviation pilots navigating in uncontrolled airspace, because reliance on the information directly provided to the pilot is maximum in that case.

As of today there is little experience with new forms of service provision, current practices show that:

1) For Core ATC Services, State-owned service providers (be they corporate structure or national administrations are covered through State liability (States being self-insured).

2) State liability is also present for non Core Services (in the case of AIS, ICAO Annex 15 has the contracting States responsible for the accuracy of aeronautical information); for example, the Internet-based AAIS service proposed by the DFS for the preparation of flights plans contains the following liability clause:

"§ 7 Liability

1. The liability of DFS shall be limited to wilful intent and gross negligence. The principles of state liability remain unaffected by the above.

2. In the case of force majeure, DFS shall not be held responsible for any damage.

3. Under no circumstances shall DFS be liable for any unsatisfactory services rendered by a third party where DFS acts as an intermediary. DFS shall not be held responsible for any damage caused by a third party, particularly if such damage is caused by foreign service providers, if DFS merely acts as an intermediary.

4. The services rendered by DFS within the scope of the AAIS do not free the pilot from his obligation to carry out pre-flight planning in compliance with Section (§) 3a of the German Aviation Regulation and his responsibility to carry out the flight in a safe manner. Even when making use of the AAIS service, the pilot shall remain responsible for any damage resulting from faulty flight preparation unless it is proven that DFS is guilty of wilful intent or gross negligence."

3) In the USA, the licensing regime of private ATS providers includes an insurance clause, similar to the insurance coverage requirement imposed to CAT operators. For example, in small airports where private contractors to the FAA provide ATS (Level I airports), the FAA requires its contractors to carry a 1 million USD insurance coverage.

4) In Europe, the publicly available version of the NATS En Route Licence (NERL) does not contain any provision setting an explicit floor in terms of liability coverage. However, the management of NATS is expected to justify every year to the Economic Regulation Group (ERG) its ability to continue its operations. That presumably encompasses any adequate measures for liability insurance.

This brief assessment of existing liability coverage practices in the field of ANS indicates that:

- Self-insurance is not an option for non-State-owned ANS operators, because the financial weight of their exposure to liability is significant

☞ Adequate insurance coverage should be (and is already) imposed by regulatory authorities for the licensing of ANS service providers,

☞ Maintaining an element of State liability in these activities (either directly or through an Agency) can be a cost-effective means to mitigate the risk that concerns about complex liability risks may block organisational innovation.

6.3.4.3. Settlement of liability litigation in relation with the provision of ANS services

ATM services are always provided on behalf of (and by delegation from) ICAO Member States, which implies that, in the absence of other specific treaty or agreement, a litigation involving an ANS provider will be brought to court in the state for which that ANS provider operates or is established.

In the case of a multi-national organisation or agency, contractual agreements define which national law may be evoked for settling contractual liability problems, and the non-contractual liability of the Organisation may also be evoked in the context of national law (cf. for example, Article 28 of the revised Eurocontrol Convention: "*The organisation shall make reparation for damage caused by the negligence of its organs, or of its servants in the scope of their employment in so far as that damage can be attributed to them. The foregoing provision shall not preclude the right to other compensation under the national law of the Contracting Parties*").

In the case of a multi-national organisation, an arbitration procedure is generally defined to settle disputes among the participants (for example, Article 34 of the revised Eurocontrol Convention elects the Permanent Court of Arbitration in The Hague).

ANS providers, be they public or private, may be brought to court when their actions (or lack thereof) are considered as a potential contributing factor to an aircraft accident.

A State and a private provider operating on the basis of State data may be simultaneous defenders as shown by the famous AIS liability case that arose in the US: the Brockelsby v. United States and Jeppesen & Co., 767 F.2d 1288 (9th Circuit 1985).

It may be useful to quote a recent summary discussion of that case:

"In Brockelsby, plaintiffs brought an action against Jeppesen -- an aeronautical chart publisher -- for wrongful death and property damage arising from an airplane crash. Plaintiffs alleged that the pilot relied upon an erroneous instrument approach procedure published by Jeppesen. The chart had been designed and originally published by the Federal Aviation Administration (the "FAA"). Jeppesen used the FAA's data to set out the instrument approach procedure in graphic form.

The plaintiffs in Brockelsby relied upon three alternative theories of liability: strict liability, breach of warranty and negligence. The court first found that Jeppesen's publication of the chart was a "product" within the meaning of the Restatement (Second) of Torts Section 402A.(51) Consequently, Jeppesen could be sued under traditional theories of product liability.

The court then rejected Jeppesen's argument that it was without fault because it accurately portrayed the instrument approach procedure provided by a third party, in this instance, the FAA. The court noted that Jeppesen "had both the ability to detect an error and a mechanism for seeking corrections" of information set out in the government charts.

Moreover, the "appropriate inquiry [for a claim of strict liability] is not whether Jeppesen caused the product to be defective, but whether the product was in fact defective." Section 402A(2)(a) provides that strict liability may be imposed even though "the seller has exercised all possible care in the preparation and sale of his product."

Jeppesen argued that it should not be "held strictly liable for accurately republishing a government regulation." The court agreed that if "a trade journal had accurately published the government's instrument approach in text form, and a pilot had used the procedures printed in the journal, the journal would be immune from strict liability." However, the court found that "Jeppesen's charts are more than just a republication of the text of the government's procedures. Jeppesen converts the government procedure from text into graphic form and represents that the chart contains all necessary information." The court also held that Jeppesen could be found negligent for failing to detect the defect in the data provided by the FAA.

Thus, Brockelsby suggests that a provider assumes a risk of liability if it changes the content of the information it transmits in any way. Indeed, even a change in the format of the information creates a risk of liability. The Brockelsby analysis has been embraced in low technology product liability cases, where intermediaries often have been found liable for the sale or transmission of a product which causes injury."

Although the US legal system is significantly different from the European in the adjudication of liability claims particularly, the general flavour of the arguments exposed in that Brockelsby case might not be much different in a European court. Points of relevance might be:

- representations made towards potential users by the service providers play a crucial role in defining their liability, even in the absence of a contractual relationship (for example, legal analyses of GPS liability have established that the many representations made by the US Federal Government to encourage the use of GPS for civil applications make it liable to compensation claims regarding the consequences of a GPS malfunction, despite the fact that the service is provided free-of-charge); as regards specifically FDP service provision, the approach we have taken of distinguishing carefully different levels of FDP service may help delineating and limiting the exposure to liability of potential service providers;
- the value-added to a State-originated service can be an important element of the commercial strategy of a service provider; however it may also entail some additional exposure to liability;
- in a litigation process, certain ANS services may be (re)qualified as products; in that case, in the European context, the provisions of Directive 85/374 on defective products may apply to General Aviation activities.

6.3.4.4. Impact of liability issues on European regulations

The multinational nature of Europe complicates a potential litigation process that would involve trans-national service providers, because a given case might be treated under a patchwork of national laws.

☞ The ideal situation would be to have an international Convention on ATM liability in Europe serving as a common framework for defining the liability regime to which any European ANS service providers would be submitted.

☞ In the absence of such a common framework, the best approach may be to extend to all ANS services the concept of a “contractual chain of liability” that was defined to address GNSS liability issues in Europe.

The concept consists in defining a cascade of service dependencies that can be derived from explicit Service Level Agreements (this conceptual model may be extended to the quasi-contracts defined by public representations made by the providers about their products or services).

The liability chain would serve as a reference model for treating non-contractual liability issues, by ascribing to every contributor a liability in keeping with its specific responsibility in the overall service provision cascade.

For example, going back to the three level liability model evoked in the preceding chapter for the distribution of AIS, we would have the following construct:

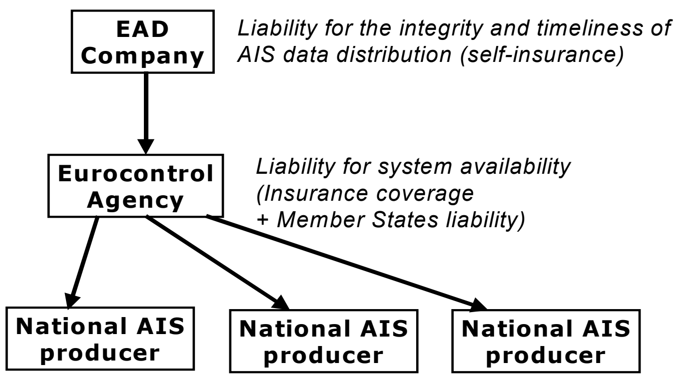

Figure 6.13: State liability for data accuracy (self-insurance*)*

For organising the liability chain in respect of FDP services, a possible (partial) construct of the responsibility/liability network could be:

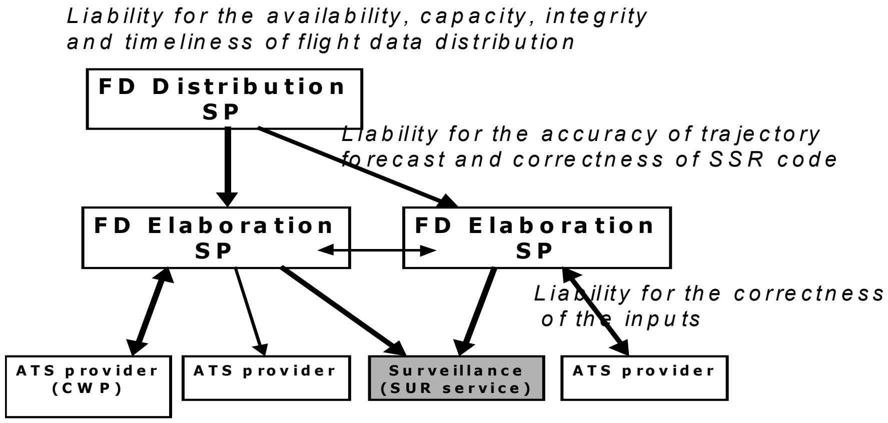

Figure 6.14: Liability for FPL transmission timeliness and accuracy

An interesting point is the dependency between the FM service and the SUR service, as a defect in the SUR service could alter the performance of the elaboration service.

Therefore, in the liability chain concept, the allocation of potential liability amongst the different service providers could be conducted on the base of the identification of breaches of SLA and other service representations made by the different providers towards their partners in the dependency network.

6.3.5. Flight data access control issues

In this section we discuss the existing legal and regulatory constraints that bear on the creation and distribution of flight data regarding their use for ATM operations. The regulation of the post-operational distribution of flight data is discussed in the section on economic regulation (cf 6.3.6).

This assessment of data access controls in turn 4 issues of relevance to the definition of the flight data access control policy:

- the mandatory nature of flight plan submission by airspace users,
- the duty for every ATS provider to provide timely and accurate data to its peers,
- the legal restrictions on the distribution of personal data,
- the security of air transport in relation with flight data exchange.

6.3.5.1. The obligation to submit flight plans

The provision of their flight intents by airspace users, in compliance with the ICAO FPL format, is a general requirement for them to be allowed to enter controlled airspace.

This obligation is imposed as a technical means for every ATS providers operating by delegation of the States to fulfil ICAO obligations of safety and expeditiousness in respect of international civil air transport.

Therefore it is a right (and a duty) for every ATS provider to be informed in advance of what traffic it is responsible for.

We have already described the operational need for extending that access right far beyond the boundary of an area of responsibility, through the notion of a much wider area of interest.

Therefore, the obligation to submit a flight plan, that may be subsequently refined into a more detailed trajectory forecast, derives directly from the provision of the ICAO Convention, confirmed by national regulations and ANS operational procedures at the European (CFMU) level.

In this context, the “owners” of the data can be said to be all the entities in charge of providing safe and expeditious ANS, but the notion of flight data ownership is of little relevance to ATM operation.

The idea that airspace users could be considered as (co-)owners of those data, because they concern “their” flight has no legal foundation: the submission of a flight plan is a public service procedure like the filling in of a data form to get a visa: you write down “your” name, “your” birth date etc. on the form but the owner of the form (with “your” data on it) is the authority that delivers the visa.

6.3.5.2. The obligation to distribute flight data

Under the principles of the ICAO Convention, reinforced by regional instruments such as the Eurocontrol Convention and other bi- or multi-lateral instruments, international co-operation is a key aspect of the safety and expeditiousness of civil air transport.

So, although an ANS service provider acting on behalf of a public authority can be considered as the “owner” of the flight data, he has a duty to provide timely and accurate data to its neighbours. Flight data used for ATM operation are not for sale (this point is discussed in more detail in the section on economic regulation). Under the ICAO rule of cost relatedness in the definition of route charges, what a ANS provider may eventually charge to its peers (and ultimately to airspace users through service charges) is the cost of producing, storing, checking and distributing those data, but no economic value may be attached to the data themselves in that context of ATM operation.

6.3.5.3. Protection of privacy and confidentiality

The national authority requiring a flight plan (or the public or private operational entity operating on behalf of that authority) is the “owner” of the initial flight plan, but only to serve the purpose of fulfilling its international obligations towards other ICAO Member States and also the missions assigned to it by national law and regulations.

As most countries and certain international organisations have a national legislation protecting the confidentiality of personal data (e.g. the revised Eurocontrol Convention contains new provisions at appendix 2.5 regarding the protection of personal data), and also in most cases the confidentiality of commercial activities conducted within the bounds of the law, the authority that “owns” the flight data can amend and circulate it to other authorities for operational purposes, yet it is also expected not to divulge those data in ways that would be a breach of national data protection laws.

Since the name of the pilot is one of the fields in the ICAO FPL format, flight plans must be considered as personal data. For example, the General Terms and Conditions of the AAIS service provided by DFS (and already evoked in a preceding section) include the following provision:

“§ 8 Data processing

DFS will store all customer data that are required to duly render the AAIS service in a database. The customer shall accept such storage of data. The regulations governing data protection shall be observed.”

Again, we can see that the notion of ownership has not much relevance in that context, as these operational data cannot be freely distributed or sold by ATS providers, but only circulated to those other actors of ATM that need them to fulfil their own operational missions.

6.3.5.4. Protection of air transport security

The general requirement for the security of air transport is another potential source of regulatory restriction on the distribution of flight data.

☞ A sound principle of security would be to limit the real time distribution of such data to those parties that can demonstrate (to some security regulator) an operational need for having access to flight intents and trajectory forecast.

☞ The notion of area of interest is also of relevance in this context of security: the demonstration of operational ATM needs could be formalised by the service providers through the definition of such areas of interest.

☞ To reinforce the security of flight data exchange, the security regulator(s) could (and in our opinion should) make mandatory the inclusion of user authentication and data integrity and confidentiality protection mechanisms in FDP service provision.

We do not discuss here data access restrictions based on national security concerns (we have briefly touched the issue of state flight data in the section on national security issues).

6.3.6. Economic regulation issues

The economic regulation of FDP service provision consists of 3 main issues:

- The justification of charges imposed in respect of that service,
- The economic status of flight data,
- The economic optimisation of service provision.

6.3.6.1. Justification of FDP service charges

The distribution of flight data for the purpose of conducting ATM operations is submitted to the same economic regime as the rest of ICAO-regulated services, that is the principles of transparency, non-discrimination and cost-relatedness should be respected and all States are expected to enforce these principles.

In practice, when an ATM service is provided by a private investor, a “reasonable return” on the capital invested is deemed acceptable by the ICAO guidelines on the determination of service charges.

In Europe, the costs of ANS provision are billed through and collected by the CRCO and are now being reviewed by the PRC/PRU as part of their performance oversight activity. IATA also attempts to monitor the cost structure of the providers.

A major difficulty here is that the accounting rules are not sufficiently detailed to make visible the budget allocated to the procurement and maintenance of FDP systems, and even less the distinction between the different types of FDP services we have discussed: all of the FDP activities are bundled with ATS services.

With current FDP systems, this separation would not be easy to achieve, because various controller tools may be part of the FDPS software.

By contrast with FDP services, AIS, MET and CNS services are already separately identified in the CRCO forms, so the cost-related justification of the charges for these other services is already available.

6.3.6.2. Economic status of flight data

Because of the ICAO-imposed obligations on the submission and distribution of flight data, we have demonstrated that the notions of ownership and economic value of operational flight data are irrelevant.

We have concluded also that, for security reasons, the real-time distribution of flight data should be restricted to those parties having an operational reason for accessing them.

☞ Since the ICAO principle of cost-relatedness applies to all ATM services, including the provision of flight data to any ATM actors, there is no need to define any additional regulation in this area.

The only issue that remains to be clarified is the economic status of flight data at the end of their operational lifecycle and whether the commercialisation of non-operational flight data should be specifically regulated.

Once the flight data are no longer operationally “alive”, they fall out of the scope of ICAO-imposed rules and those operational entities that detain them may want to distribute them commercially to any third party willing to pay for that information.

If no additional regulation is put in place, the only constraint applicable to the “post-operational” commercialisation of those data is the obligation to respect existing national legislation concerning personal data protection and commercial confidentiality.

In practice, that means that either the concerned persons should give an explicit agreement before the data are further distributed or the flight data should be made anonymous before distribution. Other possible constraints that may be imposed by existing data protection regulations are to:

- impose a suitable degree of statistical aggregation (as anonymity can be no longer guaranteed when the size of the data sample is too small),
- impose a suitable confidentiality delay before making those data available outside the ATM operation community.

With such a liberal approach, any ATM stakeholder would be free to repackage its archived flight data so as to comply with data protection law and then sell them to anybody wishing to acquire that information.

☞ As of today, the very existence of a commercial potential for the distribution of post-operational flight data is far from certain, and any specific restrictions (going beyond existing data protection legislation) could hinder the development of innovative services (e.g. marketing research) based on those data, so we suggest not to impose any additional regulation on the commercialisation of those flight data that no longer serve any operational purpose and their release would not constitute a security risk.

6.3.6.3. Economic optimisation of FDP service provision

A key problem of this study is the lack of any detailed information on the current cost of FDP system procurement, evolution and maintenance, since CRCO data are provided at the level of ATS service.

Also these financial data are provided on a global basis per ATS provider, while serious discussion of economic optimisation would require a breakdown per ACC.

To create the necessary transparency and adequacy of information, we recommend that:

☞ The CFD “steering committee” where stakeholders’ representatives participate in the decision-making by consensus, is a correct forum to discuss the requirements for interoperability and data consistency. Of course, such decision-making process is fragile, as one partner can block the progress of the group.

☞ The European Commission should work with appropriate bodies to establish access to all data necessary for comparing and benchmarking FDP systems, including their development, procurement and service provision costs.

☞ Once the Single Sky legislation is adopted, it should be a priority goal of the new Single Sky Committee working with Eurocontrol to develop and recommend the necessary implementing rules and appropriate regulatory actions by the Commission.

☞ The European Commission should impose a more detailed breakdown of costs billed through the CRCO at the level of the different functional domains (the cost corresponding to the perimeter of the FM service should be clearly identified) and per ACC.

☞ Once adequate reporting procedures are in place (whether through formal regulation and/or establishment of better accounting practices), benchmarking and cost-benefit studies could be launched to determine whether there is a rationale for unbundling, centralising and/or externalising certain elements of the FDP service.

6.4. Possible future scenarios for FDP Service Provision

In this last section we address four different organisational set-ups for the provision of FDP services, looking at the perceived pros and cons of these solutions in relation to the institutional and legal issues discussed in the previous section.

6.4.1. ATC-integrated FDP (FDP service provided on a per-ACC or per ATSP basis)

This model is the current dominant model for FDP service provision.

This model is probably the only practical approach for managing the ATC interaction part of the FDP services. That is, local copies of the flight data, managed under the responsibility of the ATSP, will have to be modified according to Air Traffic Controller instructions. So, as already explained, the different FDP services identified (distribution and elaboration of FD) may be provided in different ways. However, sticking to that model for all of the FDP services raises a number of issues.

The main advantages of this approach are:

- Familiarity and a high level of current provider acceptance
- Cost-effective maintainability (in facilities where the same staff service, maintain and modify (e.g. with software updates) a range of DP tools)
- Direct ability of ACC or ATSP managers to customise and update service requirements as well as to control quality directly
- Fewer actors may be involved in service liability
- No change in existing service licensing scheme (FDP service remains entirely within the perimeter of the Core ATC Service)

Its main drawbacks are:

- All FDP services continue to be fragmented,
- It cannot deliver new economies of scale,
- Staying within the traditional, familiar system fails to create strong incentives (which the stakeholder community believes are needed) for improving rapidly FM inter-operability and performance,
- it fails to ensure that future FDP operations provide the data consistency and predictive range required by future ATM in the Single Sky, unless a very strong common mechanism for enforcing compliance with new inter-operability and performance standards is put in place.

6.4.2. Inter-ATSP Agencies

This model already exists for the CFMU IFPS service. It can also be envisaged at a lower level of aggregation (e.g. groups of 3 or 4 countries joining efforts for developing common FDP services.) This model is conceivable for services that would yield themselves well to a high degree of centralisation (like the distribution service). However the approach of co-ordinating a joint FDPS procurement (based on a consistent set of inter-operability and performance standards) among several ATS providers would deliver the same advantages without having the important drawback of creating a significant organisational overhead, which is unavoidable with an Agency structure.

The main advantages of this approach are:

- Compatibility with the Eurocontrol Agency structure,
- Well defined institutional framework and liability coverage,
- Lower than otherwise service provision costs achieved through significant potential savings through joint procurement,
- Homogeneity of FDP inter-operability and performance on a regional (or sub-regional) level.

Its main drawbacks are:

- The lack of cost-effectiveness, because an international agency structure entails additional cost,
- The lack of institutional and organisational flexibility of an Agency structure.

6.4.3. ATSP-Industry Joint Ventures

This model already exists for the EAD company. This model is interesting for well-standardised services that would yield themselves to varying degrees of centralisation or clone replication in a distributed architecture.

The main advantages of this approach are:

- Possible articulations with the Eurocontrol structure (especially now that Article 6.3.3 of the Revised Convention allows the Eurocontrol Assembly to create subsidiaries, that could have a more flexible structure than the Agency for the purpose of providing certain services, and also of helping to clarify organisationally the separation of roles within Eurocontrol between regulatory support and service provision; e.g. a joint venture between Eurocontrol, ATSPs and the private sector could be an evolution path for the Initial Flight Plan service currently provided by the CFMU[67]) ; however, it should be noted that the involvement of Eurocontrol may complicate the picture, especially because of their involvement in support of regulatory activities: a clear separation would be needed to avoid conflicts of interest.
- Significant potential savings in both procurement and operations, as a corporatised operator would probably be more cost-effective than a state-driven agency,
- Benefits from ATS expertise in FDP service specification and operation, by contrast with a service provision structure from which the ATSP would be absent,
- Homogeneity of FDP inter-operability and performance on a (sub-)regional level, and enjoying the credibility of having ATSP on board.

Its main drawbacks are:

- Difficulties to control the acceptability by all parties of the liability coverage arrangements (the regulator being the national authority of the country of incorporation of the company, a wide consultation of other national authorities would be needed to avoid discrepancies between the perception of liability issues),
- Risk of favouring the emergence of an industry monopoly if the industry party is an FDPS manufacturer (if the industry side is only a facility management company, this risk doesn't exist).

[67] The CFMU operates a pan-European IFPS, but most ATS Provider maintain a local IFPS function for various reasons : introduction of flights arriving in their airspace without having submitted a flight plan to the CFMU, conversion of flight plans to their FDP-specific data format, willingness to maintain a minimal independent capability in case of CFMU failure, separate processing of state flights.

6.4.4. ATSP-independent FDP Service Company

This model already exists for the distribution of AIS in the USA through Jeppesen. In the field of FDP services, this model may be workable in the long term for well-standardised services that would yield themselves to varying degrees of centralisation or clone replication in a distributed architecture.

The main advantages of this approach are:

- Significant potential savings in both procurement and operations, like in the joint-venture model,
- Homogeneity of FDP inter-operability and performance on a (sub-) regional level, since such a structure cannot work without having more than one ATSP customer.

Its main drawbacks are:

- The potential complexity of liability coverage arrangements, as ATSPs would remain responsible (and liable) for the modification of flight data made through their ATC activities,
- A certain lack of credibility in relation to ATS operations, due to the absence of ATSPs in the construct,
- A risk of incompatibility with existing ATS licensing regimes (in Europe today, this concerns only NATS; but the NATS En Route Licence considers the FDP service as part of the Core Service).

6.4.5. Best compromise

The best compromise between credibility, liability coverage, cost-effectiveness and flexibility seems to be the setting-up of ATSP-industry joint ventures. However, it would be applicable only to the Flight Data Distribution service in the short term.

Anyway, too little information on the economy of FDP service provision is available to develop a robust rationale for any specific solution (cf. recommendations in the previous section for improving that situation).

6.5. Conclusion and recommendations

Our three main conclusions are that:

- There is a need to improve considerably the homogeneity of FDP service provision in Europe across so many different Areas of Responsibility; this need calls for a focused and determined service standardisation effort.
- The organisation of FDP service provision is a difficult area to deal with because:
    - It is at the heart of the ATM information exchange, and it has a strong coupling with Core ATC services, and strong dependencies on other sub-systems (environment and surveillance)
    - The multiplicity of operational constraints and the complexity of the on-going discussion on technical architecture issues makes it difficult to focus the debate at organisational issues, which are related to technical ones in a non-straightforward way
- There is room for innovation in the organisation of service provision, along three different axes:
    - the identification of finer functional levels of FDP service provision to be associated with specific provider responsibilities,
    - a thorough distinction between the ICAO-constrained management of operational flight data and their post-operational life,
    - new schemes associating ATSP providers and other industry partners to design, install and operate FDP service entities in a more flexible way.

The salient recommendations made in this chapter regarding regulatory action on the organisation of FDP service provision are hereafter-recapitulated theme by theme.

6.5.1. Decomposition of FDP services

- Consideration should be given to distinguishing formally the FD Distribution service from the FD Elaboration service. This should include a clarification in European regulation of where these FDP services would sit in respect of either ancillary services or Core ATC services. FD distribution to non ATC clients could be considered as an ancillary service that could be developed in the short term.

6.5.2. Liability

- The exposure of non-State-owned ANS providers to non-contractual liability requires that adequate insurance coverage be required in their licensing mechanism.
- The current complexity of the legal framework, especially the current patchwork of national law in Europe that is applicable to ATM liability, and also the potential multiplicity of claimants and defenders in any litigation makes the establishment of a common ANS liability framework desirable.
- Before such a long-term ideal can be achieved, extending the GNSS-defined concept of contractual liability chain would be extremely helpful to clarify the relationship amongst the different potential service providers.
- Keeping an element of State liability in the organisation of FDP service provision (either directly or through an Agency) can be a cost-effective means to mitigate the risk that concerns about complex liability risks may block organisational innovation.

6.5.3. Protection of Air Transport Security

- It is a sound principle of security to limit the real-time distribution of flight data to those parties that can demonstrate (to some security regulator) an operational need for having access to the flight intents and trajectory forecasts concerning flying aircraft.
- The demonstration of operational ATM needs should be formalised by the service providers through the definition of Areas of Interest (distinct from and potentially much wider than) their Areas of Responsibility.
- To reinforce the security of flight data exchange, the security regulator(s) should mandate the inclusion of user authentication and data integrity and confidentiality protection mechanisms in FDP service provision.

6.5.4. Economic regulation of FDP service provision

- The distribution of operational flight data is already regulated by the ICAO principle of cost-relatedness (and also restricted by air transport security concerns, as noted in the preceding section.) so no additional regulation is needed.
- As of today, the very existence of a commercial potential for the distribution of post-operational flight data is far from certain, and any specific restrictions (going beyond existing data protection legislation) could hinder the development of innovative services (e.g. marketing research) based on those data, so we suggest not to impose any additional regulation on the commercialisation of those flight data that no longer serve any operational purpose and their release would not constitute a security risk, providing other existing legislation on personal/commercial data protection is respected by the service providers

The construction of an economic rationale in respect of FDP service provision would require a detailed breakdown of CRCO-declared costs at the level of each ATS element and per ACC. Regulatory action making that information available is a pre-condition to any serious further work in that field.

To create the necessary transparency and adequacy of information, we recommend that:

- The European Commission should work with appropriate bodies to establish access to all data necessary for comparing and benchmarking FDP systems, including their development, procurement and service provision costs.
- Once the Single Sky legislation is adopted, it should be a priority goal of the new Single Sky Committee working with Eurocontrol to develop and recommend the necessary implementation rules and appropriate regulatory actions by the Commission.

- The European Commission should impose a more detailed breakdown of costs billed through the CRCO at the level of the different functional domains (the cost corresponding to the perimeter of the FM service should be clearly identified) and per ACC.
- Once adequate reporting procedures are in place (whether through formal regulation and/or establishment of better accounting practices), benchmarking and cost-benefit studies could be launched to determine whether there is a rationale for unbundling, centralising and/or externalising certain elements of the FDP service.

6.5.5. Organisation of service provision

- The best compromise between credibility, liability coverage, cost-effectiveness and flexibility seems to be the setting-up of ATSP-industry joint ventures. However, it would be applicable only to the Flight Data Distribution service in the short term.

7. FDP SYSTEM AND SERVICE STANDARDISATION

7.1. Statement of work

7.1.1. Objectives

The objectives of this chapter are to:

- Describe the overall structure of FDP-related standards in line with the functional architecture model defined at chapter 1,
- Identify which standards have to be developed to support different FDP service provision scenarios, in line with the breakdown of FDP services proposed at chapter 6,
- Propose a course of action for progressing the standardisation,
- Identify which measures could be taken by the European Commission to bolster that standardisation process.

7.1.2. Approach

his document mainly focus on the Flight Management component of the FDPS, which was identified in the first part of the I2FDP study as the best candidate for advancing standardisation and organising co-operation for FDP system development and procurement and/or service provision.

This chapter is structured as follows:

- The first section “Standardisation and Certification Processes” recapitulates the relationship between regulation, standardisation, qualification and certification activities, in the field of ATM systems and services (in ANNEX G: Standardisation and certification definition and relationship the definition of these terms and their relationship are given in a more general context);
- The second section “FDP Standardisation Framework” presents FDP interface inter-operability, performance, system architecture and system management standards, based on the FDP functional model that governs our definition of the system and service breakdown;
- The third section “Standardisation Roadmap” introduces a rationale for the evolution of current flight data exchange standards and describes the proposed content of the standardisation roadmap work programme;
- The last section “Foreseen Standardisation Mechanisms” proposes a global approach for developing implementation rules and the associated technical standards in a consistent way.

7.2. STANDARDISATION AND CERTIFICATION PROCESSES

7.2.1. ATM/CNS equipment and systems

Different from the global process for standardisation and certification described in Annex E, the current process for ATM/CNS equipment and systems is not a formal certification, since the certification function is not fully completed. The ground equipment are designed/manufactured/operated/maintained against European and National standards (e.g. MOPS provided by EUROCAE) and regulations, and the qualification is performed by the designer/manufacturer/operator.

For the time being, the regulations are mainly national, except in the field of Safety where several Eurocontrol Safety Regulation Requirements (ESARR) have been developed and published by the SRC, making them binding at the ECAC/Eurocontrol level. However interoperability and performance are not covered for the time being.

7.2.2. ATM service provision

The current situation regarding the regulation, standardisation and certification of ATM service provision is as follows:

- Each State that adheres to the Chicago Convention undertakes to keep its own regulations, its air navigation equipment and operations, compliant with Standards established by the International Civil Aviation Organisation (ICAO), unless it has notified differences with respect to its implementation of such Standards.
- There is no internationally agreed procedure to design, commission, operate or declare a new ATS system to be operational. Generally speaking, when the ATS providers belong to a State organisation, they take responsibility for the system they operate. Most States have not established an independent regulatory or certification body, which would develop requirements for systems and procedures supporting Air Traffic Services and/or assess compliance with those requirements.

However, a trend to corporatise and/or privatise Air traffic Services has led to an increasing need for establishing independent regulatory/certification bodies either on a national basis, such as in Australia and the UK (where an SRG for Safety and an ERG for economic regulation have been put in place before the recent partial privatisation of NATS), or on a European basis.

The standardisation function is performed by Eurocontrol: certain requirements, like the different levels of RNAV capability to be provided, the automatic transfer procedures to be put in place etc. are harmonised by Eurocontrol expert groups and can be seen as mandatory standards to be applied by the ATS providers under the responsibility of the States. However, their implementation is managed through the CIP mechanism, which does not make these standards formally and directly binding on the States. Also, no attempt has been made so far to undertake a systematic definition of standards for all aspects of ATM service provisions.

In the field of safety, a regulatory regime has been established for all ATM operators in Europe. The ECAC Transport ministers during MATSE/5 gave approval to that strategy in February 1997. Along with this latter decision, and under the revised Eurocontrol Convention, a Safety Regulation Commission (SRC) and Unit (SRU) have been established to deal with ATS safety regulation and safety management requirements and procedures.

The resulting ESARR documents produced by the PRC/PRU are mandatory standards bearing on ATM activities, but they are not service inter-operability or performance standards.

Some European initiatives can be identified where total or partial independent regulatory or certification authorities have been established. (e.g., UK CAA Safety and Regulation Group; the Group of Air Navigation Service, Airport and Ground Aids Safety Regulators -GAASR- which has been established on a voluntary basis by Denmark, Finland, Holland, Iceland, Ireland, Norway, Sweden and UK).

7.3. FDP Standardisation Framework

7.3.1. The objectives of FDP standardisation

Generally speaking, the development of standards may be undertaken for several purposes, which have already been discussed in preceding chapters:

- Rationalisation of R&D efforts;
- Creation of a wider common market, removal of technical barriers to competition (especially, of monopolies based on proprietary solutions);
- Facilitation of system inter-operability and adaptability, emergence of new services;
- Development of a safety certification framework, based on the thorough assessment of products and services against detailed and stringent standards.

For FDP systems and services, the need for a fully fledged safety certification framework (as implemented for aircraft equipment and systems) is not evident, although those parts of the system that directly interact with the aircraft (what we denoted as AM in our Functional Model) may require somewhat stricter certification processes than the rest of the system, especially if some data are foreseen to be uplinked directly into the FMS.

So the main reasons for developing FDP standardisation are operational and economic; this implies that a light-handed approach to FDP certification should be taken, so as to avoid destroying the potential benefits of standardisation through the creation of unnecessary system certification overheads.

In those sectors (e.g. drug development, nuclear power generation, avionics…) where safety concerns are very important, the cost of safety certification is very high: more than 80% of the development cost of a new drug are absorbed into clinical tests of its safety, which are conducted before the product is put to the market.

Therefore it is important to ensure that the scope and depth of FDP standardisation is carefully adapted to its operational and economic objectives.

7.3.2. The actors of FDP standardisation

Technical standards are elaborated by technical committees and groups of experts that work as a consensus building forum (an ISO or ICAO standard reaches the ballot phase only when all major players find it palatable.) These committees are widely representative of all the stakeholders with a technical and commercial interest in the product or service to be standardised, so as to provide for a meaningful consensus.

Depending on the context of application, some authority may make the standard mandatory by some regulatory action. By contrast, voluntary standards are put into application only though the goodwill of the participants to the process (which means that they must have an economic or operational interest in promoting it).

Being “voluntary” does not mean that the standard is not designed and applied rigorously: that adjective only points at the absence of any regulatory obligation to implement it. For example, in aeronautics, ISO 9000 standards are voluntary, in the sense that they are not mandated by a regulator, while JAR standards for aircraft and avionics equipment design, construction and maintenance are co-ordinated between and mandated by the Civil Aviation safety regulators in Europe.

The qualification of products and services against a standard is generally conducted by the manufacturers and/or the service providers, that put together adequate evidence of compliance through various means (design review, workbench testing, pre-operational trials…).

When a formal certification is required, especially due to safety regulation, some third party, duly licensed by regulatory authorities, is tasked with checking the evidence made available through the qualification process and, if necessary, it conducts additional inspections and verifications (that third party may be the regulator itself, but most of the time, the fieldwork is delegated to classification societies).

The following table summarises the different roles to be taken up by the different actors in relation to the FDP standardisation process in Europe:

Role in standardisation	Actors in the process
Elaboration	Dedicated Eurocontrol and EUROCAE groups
Enforcement	National ANS Regulators (+ European Commission)
Qualification	FDP manufacturers, FDP Service Providers
Certification	National ANS Regulators (+ classification societies)
Qualification	FDP manufacturers, FDP Service Providers

The institutional status of the standardisation-related entities is described at chapter 5.

In the rest of this chapter we limit our scope to inter-operability and performance standardisation. However, in the last section, we introduce a mechanism allowing dealing with any safety issues that may arise in connection with FDP standardisation.

7.3.3. FDP functional model

The first step towards the standardisation of FDP systems and services is to reach an agreement on a functional breakdown of the FDP into its functional components. As presented in the introduction, the most adequate starting point is the representation defined in the context of the EATMP (cf 1.4).

7.3.4. Existing Flight data Description and distribution Standards

7.3.4.1. ICAO standards

At a world-wide level, Flight Plans are distributed over the AFTN (a message-forwarding network developed in the sixties) using a standard format defined by ICAO. The flight data part of the flight plans circulated over the AFTN are summary descriptions of the departure and arrival airports, with departure and arrival time, plus a limited number of intermediate points along the route, plus the aircraft type, the flight ID or the aircraft registration number. A number of other pieces of information are also included in that flight plan, and are irrelevant to this chapter on inter-operability and performance, like the name of the pilot etc.

Neither precise calculations of flight time over various points nor the vertical flight profile can be determined from these data. In the rest of this document we shall denote that ICAO summary Flight Plan as the Filed Flight Plan (i.e. the data set filed by the Airline Operation Office or the private pilot to be granted access to managed airspace), so as to avoid any confusion.

Within each country or region, more sophisticated formats may be used but there is still a general obligation to deliver ICAO format flight plans to other countries (e.g. FAA flight plans which are encoded with a specific national format are converted into the ICAO format for exchanging data with Canada and Mexico; recently the development of a more sophisticated common format has been undertaken by the 3 countries).

In high traffic density areas like Continental Europe, ATS providers are continuously developing sophisticated tools for facilitating the management of the flights by the controllers. The impact of these tools on the data structure is two-folded:

- a relatively precise 4D Trajectory, which can be updated every time an ATC instruction modifies the flight intents; this trajectory is produced by a tool denoted as the Trajectory Predictor that includes a model of aircraft performance and that also relies on other data (take-off mass of the aircraft in some cases, MET data, AIS data…), this trajectory is also regularly updated, as the flight progresses, owing to the Correlation Manager that compares the surveillance data with the predicted trajectory;
- a number of additional attributes can be tactically attached to the Flight Plan, e.g. a Mode A/C radar code, a departure (or arrival) sequence number etc. at various stages of its lifecycle.

The FDPS can be described as a database storing more or less sophisticated Flight data (several days before departure, a partial Flight Script may be already defined for RPL in the ATFM IFPS). This database is updated by the various tools that contribute to the refinement of Flight data.

In the current implementations of ATC systems, all of the data exchange interfaces between the FDPS and the various tools that interact with it are proprietary. At the level of ICAO, only the external interfaces for exchanging filed flight plans with other FM's located in adjacent centres have been standardised.

The ICAO FPL standard is defined by ICAO Doc 4444, which is a technical companion to ICAO Annex 11 (Rules of the Air and Air Traffic Services).

The AFTN and Message Handling Service protocols that are used for the distribution of Flight Plans (and other aeronautical data) belong to ICAO Annex 10 for CNS system standards (various protocol stacks such as CIDIN, X25 and ATN are defined in that document). This study is focused on flight data interchange standards, and we do not address any ancillary communication standards supporting the wide area distribution of flight data.

At the level of the Aircraft Derived Data, an ICAO standard already exists for specifying the message structure used for downlinking data extracted from an FMS. It is part of the ADS application defined as part of the CNS-ATM Package 1 (it is denoted as the “extended flight profile contract”). That format can be used either in the context of ADS-C or ADS-B systems.

Therefore we can assume that the application data protocol used between an Aircraft Data Manager on the ground and an aircraft will be based on the ICAO ADS standards and leave it outside of our work.

There are however some issues concerning the mapping from fine-grained aircraft intent as described in the ADS messages and the coarse-grained flight intent as usually defined in ATM.

7.3.4.2. European standards

In Europe, the OLDI standard has been developed for supporting the exchange of more sophisticated Flight data than the basic ICAO Flight Plan messages (including flight progress and FDPS activation/distribution information) and it is now widely used.

The OLDI, ADEXP and FDE-ICD, which are detailed standardisation documents defined by Eurocontrol have been turned into EC standards by Commission Regulation 2082/2000.

Also, a concept of data exchange for supporting inter-centre co-ordination (SYSCO) has been developed, but not yet implemented.

7.3.5. The foreseen evolution of FDP standards

In our functional model of FDP services presented at chapter 6, we have distinguished the quality of the distribution of data and the quality of the data that are distributed. These two aspects can be standardised so as to provide for inter-operability and/or performance guarantees.

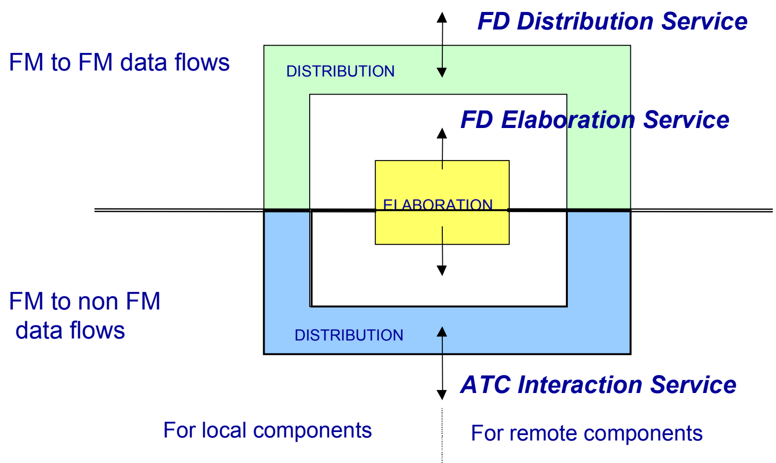

Figure 7.1: The FDP services

It is commonly agreed that the more frequent distribution of more complete data (flight script + 4D trajectory) is necessary.

7.3.5.1. FDP Service Performance Standardisation

An important finding of chapter 6 regarding the provision of homogeneous FDP services across Europe was that common performance standards were needed, so as to allow new tools such as the MTCD to work correctly on the basis of data received from another Area of Responsibility.

In our approach to service performance specifications, we have identified 2 sets of metrics:

- data distribution performance metrics, and
- trajectory prediction accuracy performance metrics.

We have also identified different levels of service provision, that correspond to specific performance levels associated to those metrics.

We can define different performance levels for inter-operability:

	Distribution performance	Correctness, accuracy performance
Current FPL messages	x	
Current OLDI messages	x	
Future 4D trajectory and FD exchanges between FMs	x	x
Current exchanges between FM and non FM systems	x	
Future 4D trajectory and FD exchanges between FM and non FM systems	x	x

As of today, existing FPL and OLDI standards do not include any explicit definition of accuracy performance (for example there is no such thing as an 95% confidence interval attached globally or individually to the ETO in the lists of way-points describing the trajectory in those standards).

However an estimate of the precision can be derived from other constraints (for example, the time constraint set to define the timely delivery of flight data at an ATC responsibility transfer point determines an upper bound on ETO accuracy).

This situation is analogous to the difference between the en route RNP levels and the approach RNP levels: the approach RNP levels include a vertical accuracy specification while the en route RNP model include only a horizontal accuracy requirement; however, the altimeter precision specification (which is defined in another standard) would allow en route RNP levels to be supplemented by a vertical accuracy constraint reflecting the precision of the altimeter.

Therefore, pre-existing data distribution standards may be revised so as to incorporate a trajectory forecast accuracy component (e.g. a confidence interval can be associated with the ETO listed in an OLDI message). In order to facilitate the migration towards the new standard it would be useful to incorporate an explicit accuracy specification into the revised OLDI standard so as to have a single data representation model, even if that specification has only a limited operational value.

Several performance levels can be defined according to the “type” of flight manager, or the nature of the tools or systems to be interfaced: CWP, MTCD, correlation manager, etc. The Flight data to be distributed and the conditions of distribution will be different.

7.3.5.2. Inter-operability standards

Our approach to FDP interoperability standardisation consists in identifying the Flight Manager with all its interfaces to the other functional modules described in the functional model.

At the level of the FDPS, whatever the service provided, it should be possible to define a data exchange standard for providing a homogeneous description of the flight data, throughout their lifecycle.

Also, there is no obvious reason, apart from history and the monolithic and proprietary architecture of existing FDPS, why the flight data messages exchanged between two FM's should be different from the messages sent locally by the FM to the various tools that use some flight data.

Therefore we assume that it is feasible (and in fact desirable) to define a Flight Data Description standard in Europe, including all of the attributes that may be created and updated during the lifetime of the flight.

The Flight Data Description standard would consist of 3 data sets:

- The Filed Flight Plan, that would be provided in the existing ICAO format
- The Flight Script that would comprise the expanded 2D route, the expected vertical profile and all the applicable constraints, dynamically updated by various sources (CWP, ATC tools, adjacent FMs)
- The 4D Predicted Trajectory, that results from simulating the flight script with a model of the aircraft and the predicted airspace and meteorological information. The form of the result is a sequence of 4D points (like the point profile of ETFMS), and possibly a airspace profile (the sequence of traversed airspace resources).

The interfaces between the Flight Manager and the other components (AI Service) can be standardised on the basis of:

- The FDP Functional Model
- A data exchange standard describing the dialogue that may take place between a given functional component and the Flight Manager; the representation of the flight data used at all the interfaces would be the Flight Data Description standard.

The notion of FDP interoperability can be defined at 3 levels:

- The inter-centre (FM-to-FM) interoperability, based on the use of the same message format and data exchange protocols between adjacent ACC Flight Managers relying on a Wide Area Telecommunication service;
- The intra-centre inter-operability (FM-to-non-FM) between a local or remote component and its FM,
- The inter-centre cross-interoperability between a local component and a remote FM.

The first level of interoperability meets the requirement for flight data exchange seamlessness within the network of all the European FM's, the second level of interoperability allows for a concentration of FDP services by fewer FM's without necessarily changing the number of ACC ("FM-less" ACC would become feasible as the result of such an inter-operability standard), while the third level of interoperability represents a further step towards the direct substitutability of FM's.

That third level of interoperability would allow any local tool to transparently get FDP service from any FM be it local, remote or central. This higher degree of inter-operability is particularly useful for improving the overall flexibility of service provision amongst ANS providers and also in relation with dedicated FDP service providers (e.g. for implementing back-up strategies, or for switching more easily from one provider to another one).

However it requires that service performance standards be specified alongside the interface standards, so that switching from one FM server to another one is operationally transparent.

Therefore, providing for a direct cross-interoperability between a remote FM and non-FM components would also require the adoption of performance standards.

7.3.5.3. Implementation standards

The standardisation can be pushed one step further, by defining an implementation model for all the functions of the FDPS.

This System Architecture standard would go beyond the interoperable interface standard by specifying for each functional interface:

- the complete protocol stack to be associated with wide area data exchange,
- the middleware and/or operating system mechanisms to be used for local data exchange (for either mono- or multi-processor systems)
- the API associated with the service primitives
- the associated performance requirements.

As another step towards system interoperability at the component level, the System Management aspects of the FDPS might also be standardised, thus allowing a completely integrated view of an open (possibly distributed) FDP system built up from various components (respecting already the operational interface interoperability standard.)

The FDP system management standard would specify:

- the basic System Management functions,
- the Managed Objects to be associated to each component,
- the system management protocols (e.g. SNMP-based) allowing the system supervisor to create, update and retrieve the different Managed Objects disseminated into the FDPS.

7.3.5.4. FDP Standardisation Overview

The following diagram summarises the different level of standardisation that can be aimed at by the different FDP policy scenarios:

- the ***specification and interoperability standards*** that describe the data exchange format and service protocols associated to the different service interfaces identified in the functional model, with basic interoperability standards expressed in terms of FM external interface only (possibly including some elements of performance specifications) and more detailed architecture standards describing the various services and their interfaces (also possibly with elements of performance specifications), so as to enable a functional “plug and play” approach.
- the ***implementation standards*** that go into further details as regards the software implementation and the configuration management, so as to reach the ultimate stage of a full fledge “plug and play” approach.

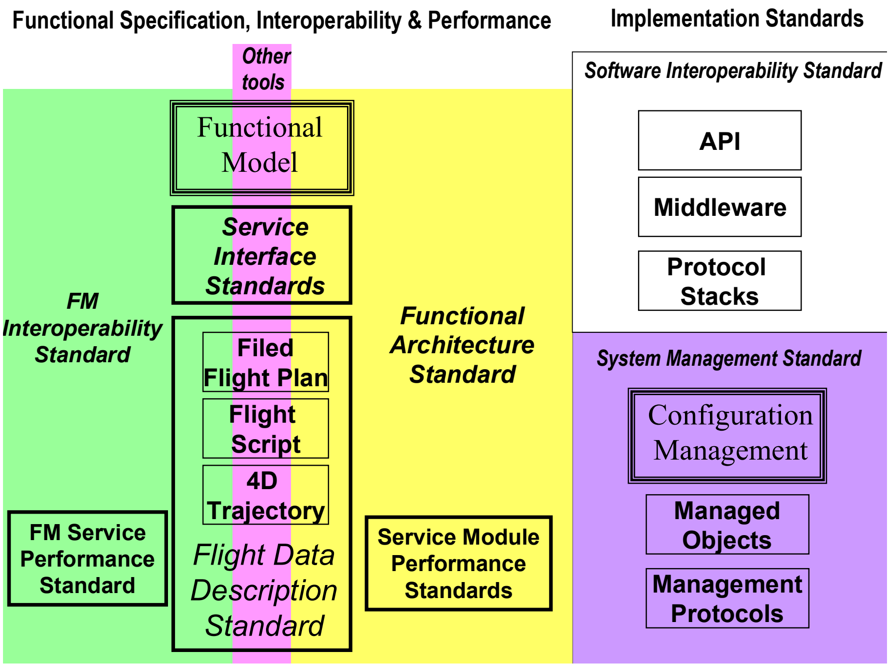

Figure 7.2: The different levels of standardisation

This diagram illustrates our approach of having a single Flight Data Description standard used to distribute flight data within the FDPS and to exchange information with other FDPS and other tools. Having the different shades of colour running across the Functional Model, the Service Interface Standards and the Flight Data Description Standard represent the notion that these 3 elements constitute the common backbone for developing the interoperability and performance standards either at the level of the FM-to-FM interface (green area on the left side) or at the interfaces of the other FDP elements, identified as specific service modules in a common architecture model (yellow area on the right side) or even for the provision of FM services to other non-FDP tools (purple area in the middle).

7.3.6. Foreseen Scope of FDP standardisation

The scope of the FDP standardisation work may vary widely depending on the ultimate objective of the standards.

In this section, we describe a scope of standardisation fitting the different system procurement and service provision scenarios described in preceding chapters.

7.3.6.1. Flight Data exchange between centres

The minimum level of standardisation foreseen for FDP systems consist in improving the circulation of Flight Data between FDP in adjacent ACCs, between ACCs and the CFMU (and/or between ACCs and some central repository, depending on the overall architectural choices).

In this scenario, there is no need for a complete agreement on a detailed Functional Model: an agreement on the functional interfaces and the message structure for exchanging data between Flight Managers is sufficient. Every FM should be able to automatically send data to any other FM when the corresponding flight enters the area of interest of that other FM (even if it is still under the responsibility of the ACC where the sending FM is located.)

More precisely what is needed here is:

- A detailed Flight Data Description Standard (including all the attributes associated with the 4D trajectory and other tools);
- A Flight Data Service Initialisation Protocol allowing an FM to notify its area of interest to its neighbours (service subscription protocol); this protocol may be strengthened by various security features (e.g. authentication of the subscribing FM);
- A Flight Data Provision Protocol allowing an FM to send Flight Data to any other FM with an overlapping area of interest, with Flight Data messages formatted according to the Flight Description Standard.

These functional standards can be further developed into implementation standards by specifying a detailed “bit-by-bit” implementation of the data structure, on the one hand, and a data communication protocol stack between adjacent FMs, on the other hand.

Since these functions constitute the cornerstone of any future large scale interoperability of European FDP systems, their availability in future FMs should be mandated by the European Commission in order to ensure that the essential requirements of seamless service as specified in Annex 2 of the Draft Final Regulation on Interoperability (see relevant text in Chapter 5). This would require the Commission, upon recommendation of the Single Sky Committee (where all Member States are represented) and acting upon the advice of Eurocontrol and Eurocae as appropriate, to issue the necessary implementing rules.

To some extent, this level of standardisation can be seen as an extension to the OLDI protocol along two directions:

- The content of current OLDI messages is refined to incorporate the Flight Data Description of the standard,
- The frequency of the current OLDI messages is significantly increased. The triggering events for sending a message are no longer limited to the events of the co-ordination and transfer protocol, but are determined by the entry of the flight in the Area of Interest of the addressee and by all changes to the flight data that impact the 4D trajectory.

7.3.6.2. Guaranteed performance inter-operability

The reluctance of ANS providers thus far to adopt FDP service externalisation has two main reasons:

- the political and organisational problem of losing control of a system which is intimately linked to their core business of providing ATC services,
- the operational dependability concern of having less confidence in the quality of an external service than in-house.

The first problem can only be solved by institutional/organisational means (e.g. by encouraging the externalisation of FDP services in a co-operative way and having that service provided by a corporate entity over which the ANS providers can exert a degree of managerial control (e.g. by being shareholders of the service vehicle company).

The definition of performance standards can significantly alleviate the second problem, that stems from a genuine operational concern about dependability: if FDP service providers have to pass some formal performance certification test to get a license, that would help making sure that the quality of their service can be in line with the expectations of ANS providers.

Obviously, a consensus should be reached on the performance metrics and performance levels to be achieved by FDP service providers: if every national regulator may set its own specific performance standards, the potential benefits of trans-national service commonality and service provision flexibility are lost.

Therefore, a necessary (yet not sufficient condition) to the development of a European-wide FDP service provision framework is the creation of a common performance standard, against which FDP service providers could be assessed for being granted an operation license.

Service performance is to be assessed through technical service parameters (quality of service metrics) which can be specified in advance, then measured at the service point of delivery by the customer and/or by other parties (e.g. a certification authority) but also through organisational and operational aspects (e.g. staff qualification and training, Quality Management policy, safety policy, procurement policy, financial solidity etc.)

Our focus in this paper is on the technical “blackbox approach” to service performance specification and verification at the point of delivery, although the wider “whitebox approach” of validating the adequacy of a number of internal policies is equally important.

The FM service performance standard should specify a number of performance metrics regarding the availability and reliability of the service provided, and also the integrity and accuracy of the flight data delivered.

It should be noted that congruent performance standards should also be established for those other systems (SUR, AM, EM, COM) on which the different functional elements of the FM depend to provide their services: e.g. the accuracy and timeliness of the TP will depend directly on the accuracy and timeliness of the EM, SUR and/or AM services it relies on in order to provide its estimates.

7.3.6.3. Modular inter-operability

If the objective is to open up the market of peripheral tools and to break the current monolithic structure of FDPS, then the first step of creating a standard FM interface is not sufficient: what is needed then is a means of compliance with the complete Functional Model, and the specification of detailed functional interfaces for the different other tools interacting with the FM.

For each component having an FM interface, we can suppose that any attributes it manipulates are already included in the Flight Description Standard.

So, what is to be specified at this stage, is a Tool Interaction Protocol describing the format and semantics of the requests from the tool to the FM and the responses received from the FM.

The whole set of these Interaction Protocols constitute the Functional Architecture Standard, in the sense that it specifies the modalities of interaction between the FM and the various local or remote tools that may use it.

This Functional Architecture Standard can be consolidated and refined by developing a performance specification standard for the service interface to each functional module (i.e. associating a set of performance metrics to every specific Interaction Protocol) and an Open Distributed System implementation standard (detailed “bit-by-bit” representation of the messages, plus the communication protocol stacks supporting the interactions).

7.3.6.4. “Plug and play” inter-operability

If a maximist view is taken for putting an end to the monolithic proprietary model of FDPS development and evolution, then the standardisation process should address directly every individual component of the Core FDP, specifying its interface with the FM and other components, so as to allow, for example, an FDP service provider to build up its own system by buying a FM from manufacturer X, a TP from manufacturer Y and a CM from manufacturer Z to build-up an FDPS in a Lego-like fashion, within the same computer system.

As illustrated by the AVENUE project, this ultimate stage of inter-operability would require a common middleware platform and the specification of APIs (Application Programming Interface) and middleware and/or Operating System mechanisms for detailing inter-component interactions between the different functions of the Core FDP, so as to reach a level of specification where software modules can be changed easily.

At this stage, we consider this ultimate level of “plug and play” inter-operability as a long term step and we do not envisage it into our standardisation roadmap.

7.4. FDP Standardisation Roadmap

In this section we describe the sequence of steps that could be taken to develop interoperability and performance standards in the FDP area, based on the architecture model of the preceding section, describing for each step the specific benefits that could be derived by ATS providers (who are the customers of FDP services and systems) the eventual FDP service providers and the system manufacturers. The processes for building up and adopting these standards is described in the next section.

This standardisation roadmap addresses only those levels of standardisation that could lead to the adoption of implementation rules adopted by the Commission for EU Member and Associated States and by Eurocontrol for its non-EU Members (the voluntary standards for system implementation are left out of the standardisation roadmap).

7.4.1. Step 1: Enhanced inter-centre data exchange standard

7.4.1.1. Technical scope

This step 1 consists of:

- establishing a common flight data representation standard,
- defining services and the associated protocols for the secure distribution of flight data in an open environment,
- providing for backward compatibility to ICAO FPL and OLDI message format, through the introduction of ad hoc service levels.

This Step 1 activity should therefore address 3 areas:

- the specification of the data representation format and semantics for the 3 data sets identified in our architecture model (Filed Flight Plan, Flight Script, 4D trajectory forecast),
- the definition of FD distribution service interfaces and their protocol (service negotiation messages, by contrast with data messages); what is foreseen here is the definition of 4 services:
  - the establishment of a secure Flight Data Exchange connection between 2 FMs, including mutual authentication and data protection mechanisms against eavesdropping and tampering (these security features should be introduced by reference to existing end-to-end security management protocols).
  - the negotiation of an Data Exchange Service Level between 2 FMs,
  - the establishment of a Data Update Subscription by one FM to another one (FM1 communicates a description of its Area of Interest to FM2 and FM2 replies by sending a description of its area of Interest, then subsequently sends to FM1 any Flight Data in its area of Responsibility which is of interest to FM1),
  - the termination of the Flight Data Exchange (disconnection).
- the definition of the different service levels to be supported for inter-FM data exchange; we can foresee 4 levels (which include also the definition of distribution rules):
  - level 1: the ICAO FPL level (only Filed Flight Plan are exchanged),
  - level 2: the OLDI level (Filed Flight Plan extended with those Flight Script data items belonging to the OLDI standard),
  - level 3: the complete Flight Script level (including any additional tactical attributes created/ used by specific tools),
  - level 4: the detailed 4D Trajectory level (including a detailed 4D trajectory calculation).

7.4.1.2. Benefits for the actors

Certain features of this Step 1 are beneficial for all the actors.

The explicit introduction of security mechanisms would be a plus for the ATS Providers in terms of operational security (today, no end-to-end protection mechanisms exist in the field of Flight Data distribution); it would be also a plus for system manufacturers as an element of promotion (improved level of security) for their FDPS products in other regions of the world; it would also be an element of facilitation for any future development regarding the unbundling of FDP services, especially in respect of national security concerns: it is likely that explicit security management requirement would be an integral part of any FDP service provision licence, even if they are not introduced beforehand in the wake of the 9/11 effect.

Defining 4 service levels within the same standard make it easier to manage the transition process on the ATSP and FDP service provision side and also to promote the corresponding FDPS products outside Europe.

The explicit introduction of Areas of Responsibility and Areas of Interest in the data exchange initiation mechanisms are important for ATS providers, as it makes it easier to trace back any responsibility/liability problems, and provides a powerful and flexible mechanism for accommodating any future change in the data distribution pattern (e.g. the same protocol can serve the needs for a central data repository to collect data from every FM located in its Area of Interest) which is very important, considering the many evolutions foreseen in the next 10 years.

The common introduction of advanced 3D and 4D data representations (level 3 and 4) will also improve considerably the seamlessness of Flight Data distribution as the ACC FMs could, either on a bi-lateral or multi-lateral basis, or through a central data repository, gain access to homogeneous and detailed trajectory predictions in their respective Areas of Interest for supporting efficiently advanced new tools that need a look-forward capability going beyond their (more limited) Area of Responsibility.

7.4.2. Step 2: Flight data distribution performance standard

7.4.2.1. Technical scope

This step 2 consists of:

Specifying performance levels at the service interface of an FM,

Describing compliance tests associated with these levels.

This step 2 activity should therefore address 3 aspects:

- The specification of the performance metrics to be used for characterising the data exchange service provided by a FM.
- The definition of minimum acceptable performance levels for various operational purposes,
- The definition of compliance testing procedures associated to these levels, including the performance requirements set on other services.

It should be noted that the performance metrics discussed here concerns the provision of the simple FM service, that is the gathering and storage of flight data over a given area of interest, and their distribution to other FM in respect of a given area of responsibility. The performance metrics associated with the notion of trajectory precision for example, correspond to the performance specification of a module within the FM (the Trajectory Predictor) and are not part of this step 2.

The performance metrics to be used in such a standard are:

- The reliability and availability of the service,
- The integrity of the data (expressed as the probability that an error is created by the FM processing between the reception of the data from another FM and its redistribution),
- The capacity of the FM, in terms of both external connectivity and internal storage capability,

- The response time for data updates (e.g. the maximum time elapsed between the reception of a Flight Data update and its redistribution).

The acceptable performance levels should be expressed as Classes of Service corresponding to typical operational use of FM systems, and reflecting sensible trade-off between different performance criteria, as all the possible combinations of individual performance levels do not necessarily make sense.

For example, one could define classes such as: ACC Backup FM Service, ACC Primary FM Service, multi-ACC Primary FM Service, Regional FD Repository Service…

These classes could be further refined by combining them with the service levels identified at step 1.

In this kind of approach, it would be reasonable to expect a higher capacity but a lesser response time from a regional repository service than from a ACC Primary FM Service.

The compliance testing would consist in running a number of scenarios (test scripts) to test the different performance parameters (e.g. filing Flight Plans up to the declared maximum capacity, measuring a number of time the delay between the ingress of a complete flight data set and its egress over the maximum number of connection interfaces).

It should be noted that the FM performance standard should be consistent with the performance expected from the supporting services (MET, AIS, Surveillance, Aircraft derived data server). For example, it is no use to specify a high level of availability of the FM service at level 3 and 4 if the feeder interface from the surveillance system is unreliable.

7.4.2.2. Benefits for the actors

The definition of FM performance standards and their association with compliance testing procedures would allow the manufacturers and their customers to define a common certification process leading to the delivery of performance compliance. The introduction of certifiable FM performance standards would be useful at 3 different levels:

- It would greatly simplify the technical specification of the invitation to tender and the subsequent tender compliance assessment during the FDP system procurement process, with significant benefits for both the ATS providers and the manufacturers, as the former would need only refer to a service level the data exchange interface and to a standard class of service to specify the external interface part of their FM, and the latter would be spared a detailed demonstration of compliance;
- It would make it easier to define common requirements between 2 ATS providers in a co-operative strategy for joint procurement of their systems, or to specify a Service Level Agreement between an ATS provider and an FDP service provider in an unbundling strategy;
- It would simplify the validation and safety assessment of FDP-dependent tools and procedures operating in a multi-ACC environment by providing a baseline for defining a homogeneous level of FM performance for all the ACC concerned.

7.4.3. Step 3: Intra-centre data exchange standard

7.4.3.1. Technical scope

This step 3 consists of:

- reusing and supplementing the common flight data representation standard defined at step 1,
- adopting a common FDP Architecture Model, and define the internal interactions between the FDP modules, and the between the FDP modules and their environment (SUR, EM, AM),
- defining services and the associated protocols for secure interactions between the Flight Manager and other Flight Data Processing Entities in an open environment (CWP, AMAN, DMAN, MTCD etc. collectively referred to as external FDPE).

This Step 3 activity should therefore address 3 areas for each type of FDPE:

- the consolidation of the data representation format and semantics for the 3 data sets identified in our architecture model (Filed Flight Plan, Flight Script, 4D trajectory forecast)
- the definition of FDPE interaction services and their protocols:
  - the establishment of a secure Flight Data Exchange connection between an FDP and external FDPEs, possibly including mutual authentication and data protection mechanisms against eavesdropping and tampering (these security features should be introduced only for supporting remote FDPE by reference to existing end-to-end security management protocols);
  - the definition for all FDPE of their interaction schemes, based on either elementary request/reply exchange or data distribution subscription protocols, depending on the type of service required;
  - the termination of the service to the external FDPEs (disconnection).

The most important type of external FDPE potentially concerned is the CWP, so as to allow a FDP to receive from the controller any input updating the Flight Data for a given aircraft, and distributing it to other FDPs.

The other external tools are less important and could be introduced as separate sub-steps.

7.4.3.2. Benefits for the actors

All the benefits identified at step 1 are also valid for this step 3, with the additional advantages that the impact on the promotion of products would be extended from FDPS systems to CWP and other external FDPE associated to that standardisation process.

For individual ATS providers, the standardisation of the FDP-CWP interface would create an element of additional flexibility for the deployment policy of their FDP systems (e.g. easier deployment of multi-ACC FDP.)

The common use of advanced data description models (level 3 and 4) for intra-centre data exchange would also make it easier for ATS Providers to develop mutual backup strategies based on the same type of co-operation agreements that exist today, even in the absence of detailed service performance specifications (in a backup service context, some degradation of the performance is acceptable).

For example, two ATSP could agree to switch their CWP to the FDPS of the partner instead of both duplicating their FDPS for the sake of dependability.

Such co-operative implementation strategies could yield significant deployment savings.

7.4.4. Step 4: FDP interactions performance standards

7.4.4.1. Technical scope

This step consists of:

- specifying performance levels at the data exchange interface for each of the FDPE identified, either lying within the perimeter of the Core FDP or interacting with it from outside,
- specifying performance levels for the accuracy of the exchanged data, between FMs and between FM and any FDPE,
- describing compliance tests associated with these performance levels.

This step 4 activity should therefore address 3 aspects:

- The specification of the performance metrics to be used for characterising the services provided at the interface between 2 components of the global system,
- The definition of minimum acceptable performance levels for various operational purposes,
- The definition of compliance testing procedures associated to these levels, including the performance requirements set on other services.

The three most important interactions to be submitted to that performance standardisation effort are:

- the FM-FM interactions;
- the CWP-FM interactions;
- the CM-FM and the EM-FM, so as define the precision performance of the TP in relation to Surveillance and Environment data;

The performance metrics to be specified are partly the same as defined at step 2 (capacity, response time) for the exchanges involving FDPE and partly new (e.g. the horizontal and vertical precision of the trajectory prediction, the error rate on trajectory deviation alerts).

Like in step 2, the specification of performance levels could be organised as discrete Classes of Service.

The compliance tests are more complex, as they require that a complete environment be simulated (the FDP to be tested has to be fed with realistic meteo, AIS and surveillance data, as well as connected to one or more CWP).

7.4.4.2. Benefits for the actors

One benefit for the ATS provider is the complete inter-operability of functional modules (but not a full fledge “plug and play” inter-operability, since the standardisation of the functional interfaces stops at the data exchange formats defined at step 3, and does not deal with API and middleware specifications, which are industrial implementation standards.)

A benefit to all is a drastic simplification of the specification files for system procurement tender, as well as a maximum flexibility for FDP service provision.

Even an only partial development of such standards (e.g. for CWP-FM interactions) would be of much value.

7.5. Foreseen Standardisation Mechanisms

7.5.1. Essential requirements in our standardisation approach

The three important features of our FDP standardisation approach that should be taken into account from the standpoint of EC regulation are:

1°) the introduction of security mechanisms (mutual authentication of FDP, protection of data against unauthorised access) which were until now absent from existing ICAO and Eurocontrol standards (the EFD-ICD mentions only a control of the peer X25 address at link establishment which provides no security guarantee); this security concern alone constitute a significant added value for our proposed roadmap;

2°) the explicit introduction of the notions of Areas of Responsibility and Areas of Interest to implement an efficient and flexible flight data access control policy;

3°) the need to guarantee the long term convergence and maintained alignment between inter-centre and intra-centre data exchange structures.

Therefore the EC should set requirements (that also govern functional systems other than FDP) to provide for:

- a mechanism allowing any FDP service user entity to securely identify itself near a FDP service provision entity, to notify its area of interest and thus guarantee the non-disclosure of flight data to unauthorised third parties;
- a mechanism allowing any FDP entity to receive all the data associated with any flight in its area of interest from another FDP entity having that flight in its area of responsibility;
- the availability of a common Flight Data Representation standard for all types of flight data exchanges between European FDP entities (not only between FDPS);

- the compatibility of that standard with existing ICAO standards at the interface with non European systems, and with the existing Eurocontrol standards for a period of time sufficient to accommodate legacy systems;
- the homogeneous specification of service capacity, availability and timeliness and of data integrity and accuracy requirements so that seamless flight data may be obtained across ATS provision boundaries, for feeding any systems having to process flight data coming from different areas of responsibility.

7.5.2. Approach for the Definition of implementation rules

One of the difficulties experienced with existing Eurocontrol and ICAO standards is that the associated data format and protocols are described at a level of detail that require frequent minor technical updates to be fed into the European standardisation process.

In this section we make recommendations to help delineate those elements of the standardisation roadmap that should be elevated to the status of implementation rules, by contrast with those implementation details that should be left at the level of voluntary compliance. Our intention is not to deliver a complete and consistent set of implementation rules but rather to define and illustrate the approach that is required for their definition.

The co-ordination process that we describe in the next section would allow conducting in parallel the consolidation of the implementation rules and of voluntary standards.

7.5.2.1. Inter-operability Implementation Rules

As regards the communication protocols to be used for distributing flight data, we do not feel it necessary or advisable to specify detailed specific solutions that could be made obsolete in a few years by the evolution of technologies.

We propose to rely on a more detailed functional definition of the mechanisms to be put in place, and to associate them with a precise yet high level definition of the acceptable means of compliance.

The resulting implementation rules could be cross-referenced to the various essential requirements previously identified (data exchange security, operational seamlessness, data access control policy, data representation convergence etc.) and supposedly incorporated in some top level regulation, so as to provide for an explicit traceability.

The following style of implementation rules should be introduced (the qualification and quantification of performance issues is addressed in the next section):

- For every pair of FDP entities having to exchange flight data, an efficient, reliable and secure end-to-end communication protocol shall be put in place
- The Area of Interest of the data user entity shall be known to the data provider entity no later than the completion of the connection establishment phase *(rationale: may be provided offline by other means)*
- The Area of Responsibility of the data provider entity shall be known to the data user no later than the completion of the connection establishment phase *(rationale: may be provided offline by other means)*

  For that purpose every FDP entity shall be designated by a unique European-wide identifier (rationale: having a unique technical identifier paves the way towards an easier evolution of service provision).

  For any communication outside a environment deemed secure (e.g. outside of an ACC), the following security mechanisms shall be put in place:

- Authentication of external FDP entities by means of an electronic signature,
- Protection against eavesdropping and tampering of real-time flight data by means of an encryption mechanism allowing for both the dynamic change of encryption keys and the introduction of an anti-replay device

- The data provider entity shall provide on a timely basis any flight data within its Area of Responsibility that fall within the Area of Interest of the data user entity; it may also retransmit flight data that come from the Area of Responsibility of another provider
- Compliance shall be demonstrated by:
  - The successful passing of connection/transmission/disconnection tests between two authorised FDP entity, and
  - Successful denial of service to an unauthorised third party, and
  - Successful transmission by the provider of flight data located in its area of responsibility and falling into the area of interest of the user.

As regards data interchange inter-operability, we have advocated the creation of a single Flight Data Representation standard, that would be functionally a superset of existing ICAO FPL and OLDI standards.

We have seen that the major improvement required in respect of the data exchange structure is the introduction of more advanced 4D representation of trajectory predictions than the list of ETO available in OLDI messages.

Therefore, the following type of implementation rules should be introduced:

- A 4D trajectory data set shall consist of an ordered sequence of points in space representing WGS 84 co-ordinates associated with UTC times,
- A Figure of Merit shall be associated to the 4D trajectory (different FoM fields may be associated to successive sub-sequences, down to individual points) in order to indicate:
  - The accuracy of the predicted location, by means of a 95 % (optionally, 99.9 %) confidence half-interval for the lateral and vertical components of the position, and a 95 % (optionally 99.9 %) confidence interval on the ETO for the longitudinal component of the position,
  - The status of the trajectory; the following distinctions shall be made:

    * whether the trajectory data are observed or predicted positions;

    * whether the trajectory data are provided under the responsibility of the sender of merely retransmitted from another FDP entity;
- The prediction and responsibility boundaries shall be assumed by the receiving part to start at the first point where the distinction appear; the provider side shall introduce adequate transition points consistent with the level of accuracy represented in the FoM field applicable to that part of the trajectory.

The detailed representation of the data structure (i.e. the concrete syntax for representing the data encoding rules for every data field) should be left at the level of the voluntary standards.

So the most critical aspect is to make sure that representative voluntary standards satisfying these implementation rules are developed in parallel, and contain an explicit demonstration of conformity to the implementation rules (e.g. a compliance matrix), so that all the actors will “naturally” develop and adopt products and services following those voluntary standards.

However, that flexibility of having the voluntary standards not directly referenced into the implementation rules might be useful in some situations (e.g. adopting a new communication protocol stack between A and B before C is ready to make the same move).

7.5.2.2. Performance implementation rules

In this section we take a closer look at the metrics and performance classes associated to the FDP services, through examples of what the corresponding implementation rules could look like.

Security performance:

- The FDP authentication and flight data protection mechanism shall protect the users against state-of-the-art code-breaking attacks until at least the completion of the concerned flights.

<u>Distribution performance (FDD or AI services):</u>

- The performance of the FDD service shall be represented by the following set of metrics:
    - Service availability: percentage of the time the service is available for a user wanting to establish a connection to the provider
    - Service reliability: probability per hour that the service connection fails
    - Service capacity: maximum number of simultaneous service connections
    - Service throughput: 95% (optionally 99.9%) maximum size of a flight data set (to be used in combination with the service capacity and the service delay to determine the peak throughput requirement)
    - Service delay: 95% (optionally 99.9%) maximum delay between the time a 95% (optionally 99.9%) maximum size flight data set is ready for emission by the provider and the time it is delivered to the user (a service connection delay may be separately introduced)
    - Service integrity: probability that an flight data set is transmitted over the connection with an undetected error
- The following classes (performance level) of FDD service shall be defined:
    - Regional IFP-FDD distribution service,
    - ACC-to-ACC nominal distribution service,
    - ACC-to-ACC back-up distribution service,
    - ACC-to-remote-station distribution service.

  (rationale: this list is only illustrative, the purpose is to show that what is important is the traceability of performance classes to operational needs, rather than the individual value assigned to every performance metrics, as, in this approach, each service class is a performance vector with one value per metric.)
- Every flight data provider entity shall indicate to the user its proposed service level of performance at the connection phase (the flight data user may specify a requested class of service).

For every performance class reasonable quantitative requirements should be assigned at the level of the associated voluntary standard. E.g. for the ACC-to-ACC nominal FDD service we might have something like:

- Service availability: 99.99 %
- Service reliability: 10^{-5}
- Service capacity: 5
- Service throughput: 1000 octets (that is, 50 kbps)
- Service delay: 10 seconds
- Service integrity: 10^{-8}

<u>FD Elaboration Service</u>

- The metrics to be used for specifying the accuracy performance of the FD Elaboration service are described in the definition of the Figure of Merit associated with the trajectory.

7.5.3. Recommended scenario for FDP System standardisation

The starting point for this scenario is:

<u>For the standardisation function:</u>

- The existing ICAO FPL SARPS and Eurocontrol OLDI standard (OLDI has also been published as a European Standard)
- The Step 1 through 4 standardisation steps described in the Standardisation Roadmap section of this document,

- The existence of a EUROCAE Working Group dedicated to the inter-operability standardisation of inter-ACC FDP interfaces (WG 59)[68],
- The existence of a EUROCAE Working Group dedicated to the definition of an industrially viable and sustainable open ATC System architecture and its standard interfaces towards the other entities in the ATM/CNS context (e.g. Radar Systems, ATFM Units, Aircraft Operators, Airports Operators, etc.) (WG 61)[69].

  The term “ATC System” in this context is used to identify all the functionality needed from the automation systems used to support Area, Approach and Tower Planning and Tactical Control Operations.

<u>For the regulatory function:</u>

- The draft Single Sky regulation on the provision of ANS service
- A soon-to-be-defined Memorandum of Understanding between the European Commission and Eurocontrol;
- The existence of an ENPRM process at the level of Eurocontrol;
- The existence of 2 bodies dedicated to regulation in Eurocontrol, the SRC/SRU that is dedicated to Safety Regulation (its rules are published as ESARR) and the RC/RU that is dedicated to non-safety regulatory activities (its creation is too recent to have produced any output). It must be noted that the RC has not the same representation level as the SRC (not all the Member States are represented.);

Considering this organisational context, the best approach to solve co-ordination problems seems to us the following one:

- include in the future Memorandum of Understanding between the Commission and Eurocontrol elements of language to the effect of the Commission issuing mandates to the Eurocontrol Agency for the preparation of implementation rules, complemented by standardisation mandates given to EUROCAE or other voluntary standardisation bodies;
- put the RU in charge of co-ordinating the production of inter-operability, performance and security regulations on behalf of the EC (including the verification of compatibility with existing ICAO rules and standards), keeping the SRC in charge of safety issues (with an obligation for the RC to have a safety review of its inter-operability and performance conducted by the SRU even when safety aspects are not deemed especially important and are not likely to lead to the production of a specific safety regulation document);
- organise the work of the RU and SRU as a co-ordinated ENPRM process (the RC/RU should validate first the inter-operability and performance aspects which are not currently covered by the SRC/SRU in their safety reviews, then, on that already partially consolidated basis, the SRC/SRU would address any safety issues arising in the preparation of inter-operability and/or performance rules);

On this basis, the FDP system standardisation would progress as follows:

- the European Commission and Eurocontrol give EUROCAE WG 59 a mandate to standardise the Core FDP system external interfaces and FM performance (steps 1 and 2 of our proposed roadmap); it is important that the WG 61 be involved from the outset so as to avoid any divergence between the WG 59 flight data interchange scheme for inter-centre co-ordination and the open architecture to be

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[68] The working group shall:

- develop standards for FDP inter-operability up to the level of detail required for the implementation (comprising application and communication layers as required) with due regard to safety, security, performance, and implementation cost. These standards shall take due accountability of existing requirements for future FDP projects.

- develop validation procedures for the standards in order to ensure that operational requirements can be met

- develop compliance checks for the implementation of such a standard (WG 59 TOR)

[69] The working group shall develop a commonly agreed set of validated standards which shall apply to the architectural design of all existing and future ATC functions for all phases of flight, independent of their physical distribution. These standards shall identify a framework of loosely coupled components. It will include the definition of each component, their relationship, interfaces, performance and quality of service to varying levels as appropriate for their validation, maintainability and evolution.

Furthermore, the working group shall specify a methodology for verification of compliance, applicable to products implementing the resulting standards developed by the WG. (WG61TOR) standardised by WG 61; also the 2 WG should share the same functional model and data flow representation of the FDP and of its relations with the rest of the ATM/CNS system;

- the European Commission tasks the RU to conduct a ENPRM process (in co-ordination with the SRC/SRU for safety aspects) leading to the drafting of the proposed regulations (implementation rules in the Commission language) associated to these standards which the Single Sky Committee would endorse for Commission adoption;
- the European Commission and Eurocontrol give EUROCAE WG 59 or 61 (and/or another new WG) a mandate to standardise the functional architecture of the FDP system, its external interfaces with other FDPE and the associated performance requirements (steps 3 and 4 of the proposed roadmap).

7.5.4. Recommended scenario for FDP Service standardisation

FDP Service standardisation should start on the same basis of inter-operability and performance standards as the standardisation of the FDP system.

Additional technico-operational requirements for service approval (e.g. personnel qualification, operation and maintenance procedures) should be defined on the basis of the classes of service identified in step 2 and step 4 (different requirements might apply depending on the target service level) and lead to the establishment of a complete FDP Service Performance standard, to be developed and adopted through the same kind of ENPRM process involving the RC/RU and SRC/SRU as proposed.

Any ATS provider wanting to establish a Service Level Agreement with another ATSP or some other FDP service entity could make reference to that Service Performance standard

Non-technical requirements on FDP service provision (liability insurance, national security issues) should be left under the responsibility of national authorities, the role of the European authorities being limited to the verification that no undue distortion of fair market access rules is introduced by those non-technical clauses.

7.5.5. Qualification and certification issues

Considering the current limitations of both ATM system and service certification processes, there is certainly a need to strengthen those functions, so as to reap all the benefits expected from performance standardisation for both the FDP manufacturers and their customers in Europe and elsewhere.

The current process is based on:

- National-only regulations regarding the product qualification and the service authorisation regimes,
- Qualification of equipment conducted by the manufacturers,
- On-site installation verification conducted by the ATS providers,
- Operational service approval given by the national safety regulators.

If FDP system interoperability and performance standards are developed in Europe, the qualification and certification process could be streamlined so as to identify a generic pan-European part that could be “factorised” and a customised part that would remain under the control of national authorities.

Therefore, we can recommend the following approach:

- create a European-wide certificate for Core FDP systems based on the EUROCAE standards described in the roadmap,
- for the legacy part of step 1 interoperability (backward compatibility with ICAO FPL and OLDI) it could be feasible to rely on industry qualification and self-assessment,
- since the thorough testing of an FDP would require a heavy simulation environment (including the feeding of realistic environment and surveillance data to the tested FDP) it could be a cost-effective approach to establish a single European facility for conducting FDP conformance testing and deliver step 1 then step 3 inter-operability and step 2 then step 4 performance labels, but any specialised

qualification entities (e.g. an ATS provider with extensive simulation capabilities) may apply for a certification license near some national regulator,

- when the standards and associated performance labels have been in application on a voluntary basis for some years, issue a regulation imposing the recognition of those labels and mandating their use in call for tenders for FDP system procurement,
- keep the verification of any local (i.e. not impacting inter-centre interoperability) deviations from the standard (e.g. caused by legacy systems), the supervision of system installation and the operational service approval under the regulatory authority of national safety regulators.

7.6. Standardisation process

7.6.1. General description

Our model is based on the three layers introduced in the new regulation (cf 4.4.3.1.)

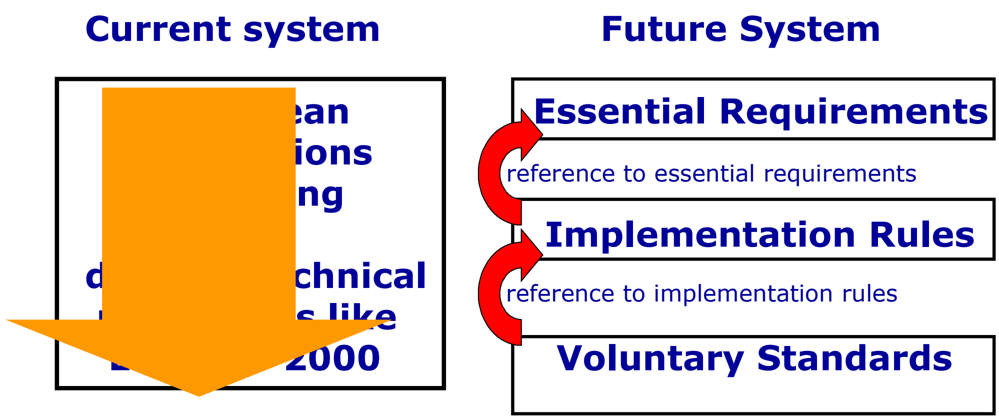


Figure 7.3: Differences between the current and the future systems.

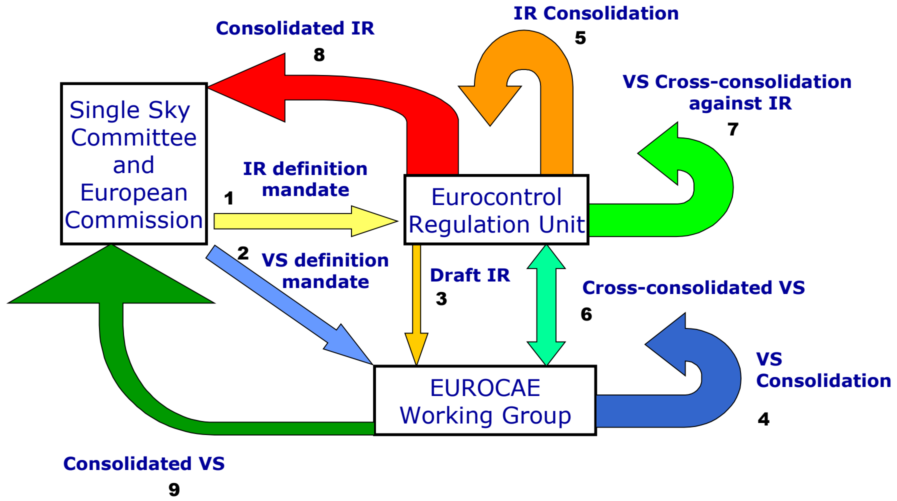


Figure 7.4: Links between the different bodies

In our model, the 2 layered process is managed as follows:

- the Commission issues in parallel an IR (Implementation Rule) definition mandate to the RU (1) and a VS (Voluntary standard) definition mandate to a EUROCAE WG (2),

- as soon as a stable draft version of the IR document is available, it is fed to the EUROCAE WG to help them consolidate a VS consistent with the expected IR (3),
- the RU co-ordinates the ENPRM process for both layers, liasing with other interested bodies (ICAO EUR, Eurocontrol expert groups, SRC/SRU etc.),
- when EUROCAE have technically consolidated their draft VS (4), it can be cross-consolidated by the RU against ICAO and Eurocontrol regulations (7),
- at the end of the ENPRM process the consolidated IR are delivered to the SSC and the Commission by the RU (8) and the cross-consolidated VS are delivered by the EUROCAE WG to the Commission (9).

7.6.2. Planning and scheduling

The minimum starting point on the European Commission side to initiate the standardisation process is the definition of the 2 initial mandates required covering step 1:

- A mandate to the Eurocontrol RU for defining a set of stable Implementation rules addressing FM-to-FM inter-operability (including a cross-reference table to the essential requirements) and to co-ordinate the ENPRM process for the consolidation of the associated technical standards
- A mandate to EUROCAE WG 59 for defining the corresponding technical standard (including the definition of acceptable means of compliance and a cross-reference table to the implementation rules

The corresponding tasks for step 1 are:

- T1.1: the drafting by the RU of the implementation rules,
- T1.2: the consolidation by the RU of those implementation rules through its ENPRM process,
- T1.3: the drafting by EUROCAE WG 59 of the FM-to-FM inter-operability standards
- T1.4: the consolidation of those standards through an ENPRM process managed by the RU.

With a view to pursuing an aggressive schedule, it may be assumed that going through the ENPRM process (on the base on a good initial draft) should take about 18 months until final publication, while the initial drafting activity would take about 6 months. As the completion of the technical standards will need a stable draft of the implementation rules, at least 3 additional months would be necessary to stabilise the draft standard and cross-reference it carefully to the implementation rules (i.e. the consultation phase of the ENPRM process for the technical standards would lag the same stage for the implementation rules by at least 3 months).

In this section, we have also assumed that the EATMP functional model of the FDP is adopted as the common reference for describing the different systems, modules and their functional interfaces (otherwise some additional lead time would be necessary to reach an agreement on another system and service description framework.)

The following Gantt chart summarises the degree of parallelism achievable within step 1 of the process according to these synchronisation constraints:

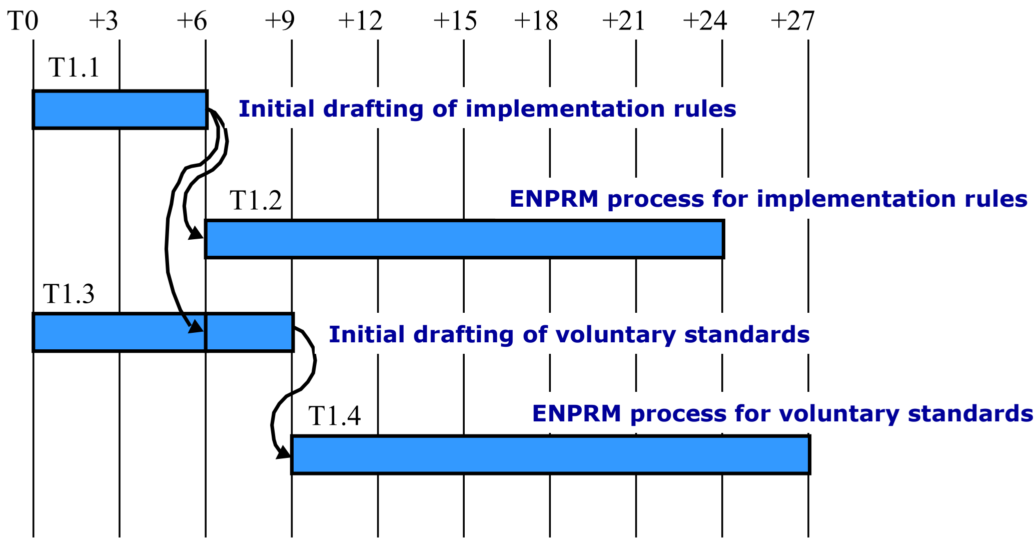


Figure 7.5: Step1: Co-ordination IR and VS layers

Step 1 and 2 have the same structure and can be run in parallel to a large extent. However step 1 will be easier to start with because of the existence of previous reference material (the FPL and OLDI standards) that can be built upon.

Step 3 and 4 can be defined only generically for non-FM interfaces, and have to be instantiated for each type of FM-FDPE interaction (we have indicated that a key issue was the FM-CWP interoperability standard). In theory, several instantiations of these steps could be run in parallel, but the availability of adequate expertise will be a constraint. There is also a risk that sub-optimal data representations (e.g. duplication of information or adoption of different patterns for similar additional attributes) result from such parallelisation. Therefore we recommend focusing the first instantiation of steps 3 and 4 at the FM-CWP interface.

It can be expected that the initial definition of the technical standards would take a little longer (1 year instead of 9 months), if only because no internationally approved reference material exist, although some more or less formalised national standards might already exist.

As regards instantiations of step 4, they could be put in parallel with the corresponding instantiations of step 3, in the same way as step 2 with respect to step 1.

The FM-to-FM accuracy part of step 4 can be started independently from step 3.

However, two other constraints have to be taken in account:

- The accuracy performance model for step 4 is derived from the accuracy representation metrics defined in the trajectory data exchange part of step 1, so step 4 cannot start before the initial draft technical standard for step 2 has been produced ;
- Ascertaining the feasibility of any accuracy performance classes defined in the technical standard part of step 4 implies that at least draft minimum performance standards already exist for environment and surveillance data service provision, which implies a lead time in the order of 9 months to one year (supposing that a performance standardisation mandate is given in parallel for environment and surveillance)

Here is a tentative global schedule showing step 1 and 2, plus the FM-to-FM part of step 4 and a FM-CWP instantiation of step 3 and 4, over a total time span in the order of 3 years and a half:

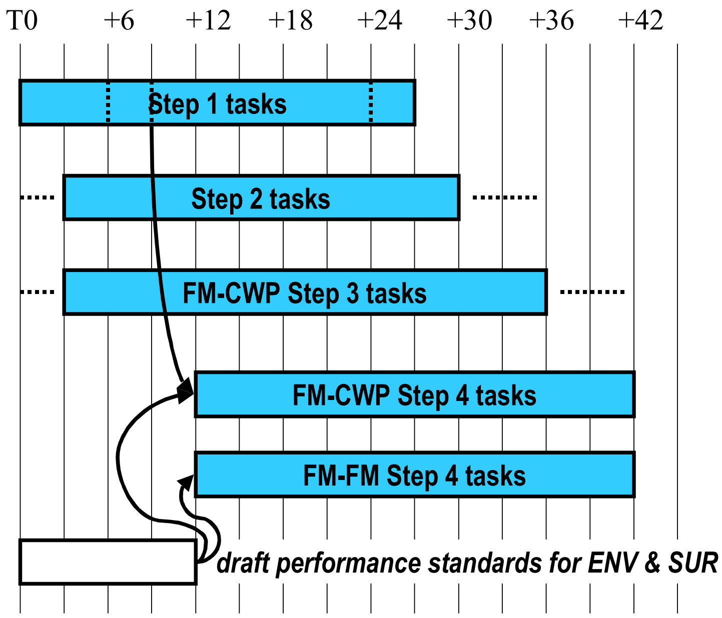


Figure 7.6: Overall schedule for the 4 steps

7.7. Conclusions and synthesis of recommendations

Our key conclusion is that the improvement of security, efficiency and operational seamlessness makes it necessary to improve significantly the homogeneity of performance in the elaboration and distribution of flight data, and that the best way to make progress in that area is through an ambitious and well-structured FDP standardisation programme.

Our main recommendations on the approach to be followed for designing and conducting the FDP standardisation process are to:

- Distinguish the Flight Data Distribution Service and the Flight Data Elaboration service,
- Address first the FM-to-FM data exchange inter-operability issue, then extend the approach to performance guarantee issues and then to the interactions between FM's and other FDP entities (especially CWP)
- Do not forget that the performance of the Flight Data Elaboration service depend on the performance of the environment and surveillance data provision services, and that the availability of minimum performance standards in these two domains is a pre-requisite to the completion of FDP performance standards
- Address in parallel the production of binding Implementation Rules and of the detailed voluntary standards designed to satisfy those implementation rules
- Develop a certification environment for products and services
- Mandate the Eurocontrol Agency for developing stable Implementation rules (cross-referenced to Essential Requirements) and for co-ordinating the ENPRM process leading to their adoption
- Mandate EUROCAE and/or other representative expert Working Groups for producing the detailed technical voluntary standards associated to the implementation rules.

ANNEX A: ASSOCIATED DOCUMENTATION

A.1 Internal project documentation

Code	Title	Reference	Date
A1	EC Contract		
A2	Sofréavia technical proposal	ATMC/P7901/PR1021-Version 1	18/05/01
A3	European Commission Invitation to Tender n°TREN/F2/11-2001.		17/04/01
A4	Project Management Plan	ATMC/C1196/PMP_vr	Release in force

A.2 Sofreavia Quality Documentation

Code	Title	Reference	Date
B1	Quality Manual		Release in force
B2	QA procedures n°14 – “Management de projet”; n°18 – “Sous-traitance”; n°22 – “Réalisation des études de conseil”; n°26 – “Maîtrise des documents du dossier d’affaire		Release in force

A.3 Eurocontrol Documentation

Code	Title	Reference	Date
C1	Call for tender AO/05/HQ/JR/01-EFDAS Technical Feasibility Study	PROC/JR/AO/0501-L1	29/01/01
C2	EFDP Procurement Specification Release 6		1997 - 1999
C3	FDPS Interoperability Study Report		1997
C4	Eurocontrol ATM strategy 2000+		
C5	Potential Applications of Collaborative Decision Making Final Report		
C6	Multi-Sector Planning discussion document	V1.22	
C7	System Supported Co-ordination (SYSCO) - Concept and functional Description - ed 1.1		
C8	ARTAS web site		
C9	CFMU web site		
C10	Comparison of flight data in CFMU and ATSUs	(Sofréavia)	09/01
C11	ASTOR Final Report. Quality of Service Template for Operational Requirements		1998
C12	Eurocontrol SCS Overall EATMP Architecture Specification	Management overview Production of overall architecture: Strawman	2000 2001
C13	Study on the regulation of airspace management and	(Wilmer, Cutler & Pickering)	04/2001

Code	Title	Reference	Date
	design (Final Report)		
C14	Papers issued from the Workshop “Development, Validation and Standardisation of ATM systems”		6-7/11/2000
C15	Separation of the regulatory and service provision functions (Action Paper)	PC/00/7/2 3.2.00 ITEM 8	?
C16	Proposal for a standardisation framework (Action Paper)	EATMP AP/ACG/9/12	30/08/00
C17	Supplier relations & policy	Final report 1E.0	25/03/98

In input C1, Eurocontrol made proposal for a study of the technical feasibility of a logical flight data server.

Input C3 contains inter-alia a set of FDPS High Level Interoperability Requirements derived from operational concepts covering the period 2000-2015 and a description of the data items (including quality of services) involved in interoperability issues. It was made by Eurocontrol and the larger Service Providers.

Input C2 is a result of eFDP Programme involving Eurocontrol and the larger service Providers. Its contains an FDPS Specification including Interoperability requirements, which is now being used as a basis for procurements of new generation FDSPs.

All the requirements of Input C3 were taken over and refined by the eFDP Programme into Input C2. However, there is still information in Input C3 that is not in Input C2, such as the discussion of architectural options.

Input C4 contains useful information about medium to long term ATM strategy.

Inputs C5 and C6 describe current thinking about some relevant future concepts to be supported by a FDP Europe-wide server.

Input C7 describes the current status of interoperability for system co-ordination functions.

Input C8 describes a project in the surveillance domain having the function “server”.

Input C9 describes the plans for the Central Flow Management Unit, including the IFPS and ETFMS systems.

Input C12 presents the overall architecture of a CNS/ATM system that would support the evolution up to circa 2010. It is the umbrella architectural model of Eurocontrol for more detailed models devoted to each segment. In particular, the model incorporates the Flight Manager component, belonging to the cross-domain cluster of components.

Input C13 gives an example of regulation issues in a domain closed to ATM.

Input C15 explains how the separation of regulatory and service provision could be made inside Eurocontrol.

Input C16 proposes how standardisation can be managed inside Eurocontrol.

Input C17 presents the proposals for improving the status of issues identified as hampering the optimal use of industries capabilities for a cost-efficient development of ATM systems.

A.4 General Documentation

Code	Author	Title	Reference	Date
D1	EC	Single European Sky – Report of the High Level Group		24/11/00
D2	TORCH CONSORTIUM (for	TORCH Definition of the Operational	TOR/AEM/WP2/22DA2	

Code	Author	Title	Reference	Date
	EC)	Concept	2.doc	
D3	AVENUE CONSORTIUM (for EC)	AVENUE SSDD part 1: Generic Aspects	D1_ch_1&2_4.doc (site www.eurocontrol.fr/projects/avenue)	12/05/2001
D4	AVENUE CONSORTIUM (for EC DGTREN)	INTERFACE REQUIREMENTS SPECIFICATION (IRS)	D1_ch_1&2_4.doc	05/04/2001
D5	EC	Communication from the commission to the council and to the European Parliament (draft)	None	Draft that circulated in October 01
D7	IATA	Five points Action Plan for ATC delays in Europe		
D8	EC	Single European Sky - Regulatory Frameworks sub-group - draft final report		05/06/00
D9	Ben Van Houtte – (EC – DGTREN)	The single European sky –	Presentation to ATC Maastricht 2002 Conference Information	06/02/02
D10	Philip Hogge (Eurocontrol – PRU)	Measuring and benchmarking ATM performance	"	"
D11	Marc Baumgartner, EVP Europe (IFATCA)	New technologies, Institutional arrangements and controller concerns	"	"
D12	Job Brüggen (Phare-X association)	Pluriformity of the R&D ATM lanscape	"	"
D13	Robert Brown (AMS)	Capacity, Partnership, Competition	"	"
D14	J. F. de Villoutreys (Thalès ATM)	Industry views on partnerships, competition and technical solutions to capacity enhancement	"	"
D15	Craig Sinclair (New Zealand Airlines)	Creating Alliances between ANSPs & Industry Partners	"	"
D16	Jean-Marc Duflot	Artas surveillance processing and distribution (slides)	2nd Symposium ATM R&D	18/06/01

The finding of the Final Report of the HLG (D1) have been taken as the governing strategic policy guidance for this Study. It has used the results D8. The document D5 (today in a draft version) translates in Community law the conclusions of the High Level Group on the creation of the Single Sky.

Input D2 describes concepts for bridging the gap between ATFM and ATC.

Input D3 gives a logical model of ATC functions, in particular those linked to the Flight data around the module FDPD: flight data processing and distribution. The goal, context, services of the modules are described. The interfaces between these modules are detailed in D4.

D6 and D7 give the view of the ATS providers and the Airlines on improving ATS provisions.

D9 to D15 are issued from presentations that have been done during the ATC Maastricht 2002 Conference Information “New strategies and institutions for ATM at national and European levels”.

ANNEX B: GLOSSARY

4D	Four-dimensional
ACC	Area Control Centre
ACI	Area of Common Interest
AFAS	Aircraft in the Future ATM System
AI	ATC Interaction
AM	Aircraft Derived Data Manager
AMAN	Arrival MANager
ANS	Air Navigation Service
AoA	Area of Authority
AOC	Aircraft Operation Cell or Centre
AoI	Area of Interest
AoR	Area of Responsibility
API	Application Programming Interface
APP	Approach Control Centre
ATC	Air Traffic Control
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATS	Air Traffic Services
ATSP	Air Traffic Service Provider
ATSU	Air Traffic Services Unit
CAA	Civil aviation Authority
CAP	Controller Accessed Parameters
CASA	Computer Aided Slots Allocation
CDM	Collaboration Decision Making
CFD/	Consistent Flight Data /
CFDSG	Sub Group
CFMU	Central Flow Management Unit
CNS	Communication-Navigation-Surveillance
CWM/CWP	Controller Working Manager/Position
DMAN	Departure MANager
EAD	European Aeronautical Data
EATMP	European Air traffic Management Programme
EC	European Commission
ECAC	European Civil Aviation Conference
ECIP	European Convergence Implementation Programme
EFDAS	European logical Flight DAta Server
eFDP	European Flight Data Processing
EM	European Manager
EOA	EATMP Overall Architecture
ETFMS	Enhanced Tactical Flow Management System
EU	European Union
FDD	Flight Data Distribution
FDE	Flight Data Elaboration
FD/FDP/ FDPS	Flight Data / Flight Data Processing / Flight Data Processing System
FLIPCY	Flight Plan consistency
FM/FMS	Flight Manager / System
FPL	Flight Plan
FPM	Flight Plan Monitoring
FPP	Flight Plan Processing
HLG	High Level Group
ICAO	International Civil Aviation Organisation
IFPP	Initial Flight Plan Processing
IFPS	Initial Flight Plan Processing System
IOP	Interoperability
ISO	International Standards Organisation
MSP	Multi-sector planning
MTCD	Medium term conflict detection
ODT	Operational Requirements and ATM Data Processing Team (Eurocontrol)
OI	Operational Improvement
OLDI	On Line Data Interchange
PRC/U	Performance Review Commission/Unit
RFT	Request for tender
RC/RU	Regulation Commission/Unit
SAP	System Accessed Parameters
SRC/SRU	Safety Review Commission/Unit
STCM	Short Term Conflict Manager
TACT	Tactical System
TOR	Term Of Reference
WG	Working Group
WP	Work Package

Institutional: Descriptive of an organisation or process created to embody, protect or establish values.

Regulatory: Descriptive of standards that seek to implement norms and of processes designed to review, investigate, evaluate and then approve, condition or deny actions as well as to determine, impose or recommend sanctions.

Policy/legal process: The framework that: defines and adopts norms; establishes or modifies institutions; develops and adopts regulations.

ANNEX C: QUESTIONNAIRE SENT TO THE STAKEHOLDERS

INTRODUCTION

Considering the deficiencies in existing Flight Data Processing (FDP) systems, the European Commission sees need now for an investigation of European-wide organisational and funding mechanisms and structures for the common and efficient specification of interoperable systems in the field of Flight Data Processing, their development, and provision of services based upon them.

In this context that the European Commission (through DG TREN) has launched the study called "FDP Institutional Issues".

The purpose of this study is to investigate the institutional issues that could be raised by more intensive co-operation of actors in the specification, development and implementation of Flight Data Processing systems and the provision of services based thereupon, including the distribution of European-wide, ground-ground and air-ground consistent flight data.

The results of this study will be used by the EC to:

1 - facilitate or mandate (by developing the corresponding legal framework), as appropriate, the suitable mechanisms and make available the necessary funding to support these common projects;

2 - facilitate the development of and possibly mandate the use of standards in the area of Flight Data Processing in order to simplify the construction of new systems, bring interoperability to the required level and drive industry;

3 - consider conditions needed for the innovative economic exploitation of the services provided by the new systems developed,

and so will participate to the elaboration of detailed proposals completing the recent legislative proposals made by the EC.

The bottom line is to contribute to the solution of the flight delays and airspace capacity problems by addressing the interoperability deficiencies and limitations among FDP systems on the ground – taking into account air-ground consistency issues - and act accordingly at the legislative level.

To define this strategy, all stakeholders will be consulted (either directly or through professional associations), through interviews and workshops where they will have the opportunity to express their needs, plans, technical and business choices and vision for the future.

This questionnaire is the support tool for such interviews.

METHOD

In order to improve the operational and technical compatibility of FDP systems in Europe and to introduce more efficiently new concepts and new technology, a new policy could be built around FDP development and services provision. This policy is an input for the definition of the architecture of the future FDP systems. On the other hand, the new policy is constrained by technical feasibility, legacy systems and current organisation.

This questionnaire consists of 13 questions, 5 relative to technical and organisational issues – they are supported by three possible architectures we present first (page 4 to 6) - and 8 questions relative to institutional issues.

We append as an annex the definition of FDP in a broad sense as it can be derived from the EATMP architecture. The interviewed people are supposed to be familiar with ATM acronyms.

CONFIDENTIALITY AND CONTACT INFORMATION

This survey is distributed to a wide range of stakeholders who are concerned by FDP Institutional Issues.

The questionnaire is being sent in advance of the interview to give you an opportunity to identify and collect relevant information. Some parts of the questionnaire may not be relevant to your organisation and can be ignored.

All responses to the questionnaire and any data supplied will be kept strictly confidential within Sofréavia and the European Commission. We will not attribute any views to either you or your organisation, except if you urge us to do so.

A member of the study team will contact you shortly to arrange an appointment. Should you require further information, please feel free to contact:

Joël MOYAUX Project Manager

Moyauxj@sofreavia.fr +33 1 41 23 48 18

PROFILE OF PERSON CONSULTED AND HIS/HER ORGANISATION

Name: ....

Organisation: ....

Role in the organisation: ....

....

....

....

Address: ....

Tel: ....

Fax: ....

Email: ....

SYSTEM ARCHITECTURE AND ORGANISATIONAL ISSUES

UNDERSTANDING THE SCENARIOS

We would like to know about your vision of the "best architecture" for future FDP systems and the reasons for this choice. In order to do so, we define three possible architectures, propose several possibilities for the organisation of system development and provision of services and put forward a set of evaluation criteria.

Whatever the technology used for each target architecture, there will be several systems deployed on different sites, connected by different networks, according to an overall distribution scheme over the ECAC region. According to the usual terminology, the systems will fall into one of the following classes:

- Operational systems, which provide the services described in the logical architecture and manage the corresponding data. When operational data are replicated in several places, operational systems hold the master copy (this reflects the data ownership of the system user).
- Data warehouse systems, which retrieve data from other nodes, to build a consolidated new database, applying if needed data fusion to solve heterogeneity issues. The new database is made available to client systems for further processing. One key feature of a data warehouse node is that its data cannot be modified by the client systems, otherwise, they would become inconsistent with original operational data.

The scenarios are related to the allocation of data and services from the logical architecture to various distribution schemes, in terms of

- Sites:

  for ATS:

  - Local units: ACC, APP, TWR control centres;
  - National units: National Airspace Management Cells, AIM authority;
  - Regional or central ATS units: IFPS Haren/Bretigny, CFMU Haren

and

- Scope[70]:
  - Sector, ATS unit, region, and world.

We take for granted the existing or planned European central systems: IFPS, EAD, and ETFMS (which incorporates the current TACT system).

In our scenarios, the ADD (Aircraft Derived Data) Manager is strongly connected to the Flight Manager in ATSUs in order to cover air-ground Flight Data consistency.

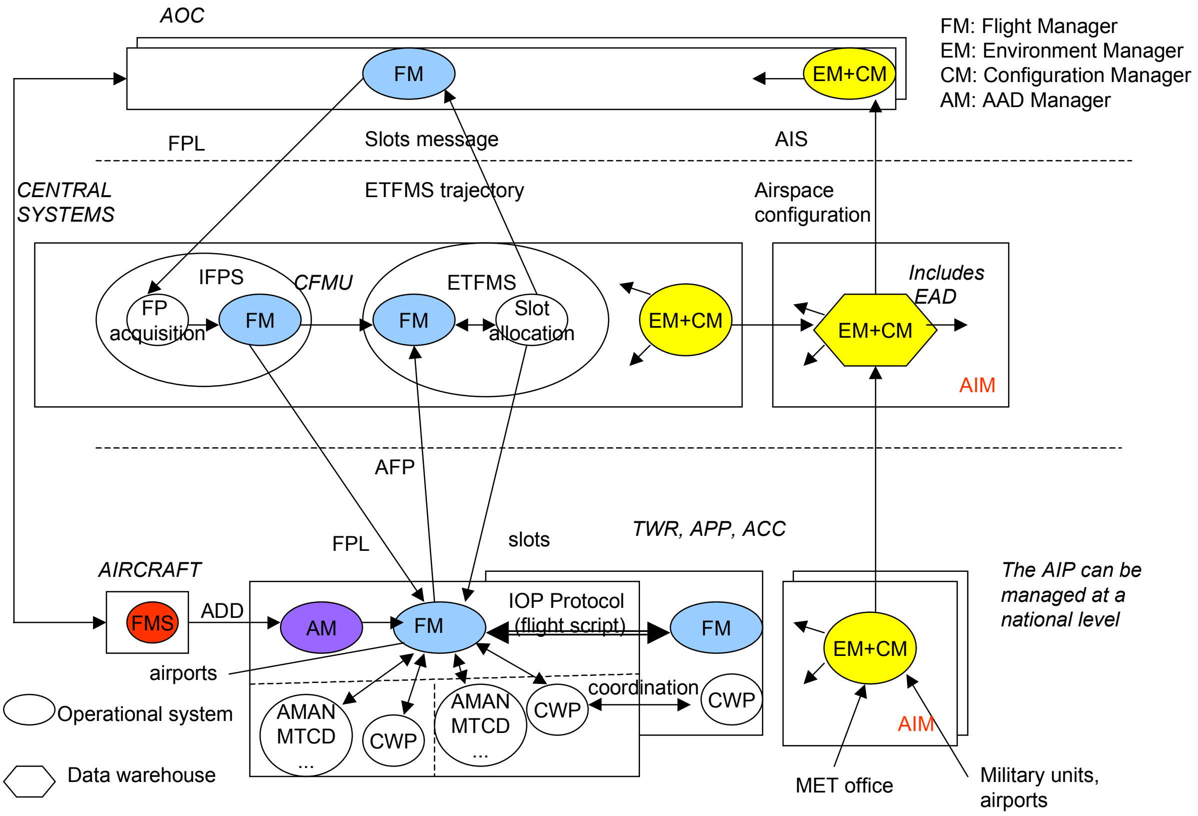
We consider that the surveillance segment is sufficiently flexible to be adapted to any scenario, in most cases co-located with the Flight Manager.

The main scenarios identified are, in loose terms:

- A network of enhanced local systems, located in ATC units, but "open enough" to provide data to non-ATC users and compliant with more stringent consistency requirements with other ATSUs.
- A fully centralised architecture, whereby data and services are available at one (or a few) locations in the ECAC region.

- A "distributed flight data server with central data warehouse" approach, whereby data that result from local processing in the nodes of the server network (for example ATSUs, CFMU) are made available in the whole ECAC region.

Please consider the following possible architectures:



SCENARIO 1: FEDERATION OF LOCAL ATC SYSTEMS + CFMU

FIRST SCENARIO: Federation of local ATC systems + CFMU systems

Scenario 1 is an improvement of the current architecture.

The FD consistency is obtained through:

- An improvement of official publications specifying conditions of use of airspace and route network, the use of common concepts and terminology on an European scale,
- The consolidation at an European level of the environment and configuration data (including cross-border management), offering an easy access point,
- A higher quality of flight data, static and dynamic environment data exchanges between all the stakeholders (including air-ground).

The Areas of Interest (AoI) of ATSUs are extended to cover ATSUs' needs concerning the new tools which are implemented locally (e.g. conflicts beyond the border). Each FM calculates the trajectory for one or several AoI (e.g. en-route + TMAs). In other terms, FM could be local or regional. As the AoI of two neighbouring ATSU have a common part, the trajectories calculated by the two FM could give different results. Exchanges between ATSUs allow a better consistency but do not guarantee identity of results. Correlation, flight plan monitoring are co-located with the FM. The FM monitors the distribution of FD to the tools and the other clients.

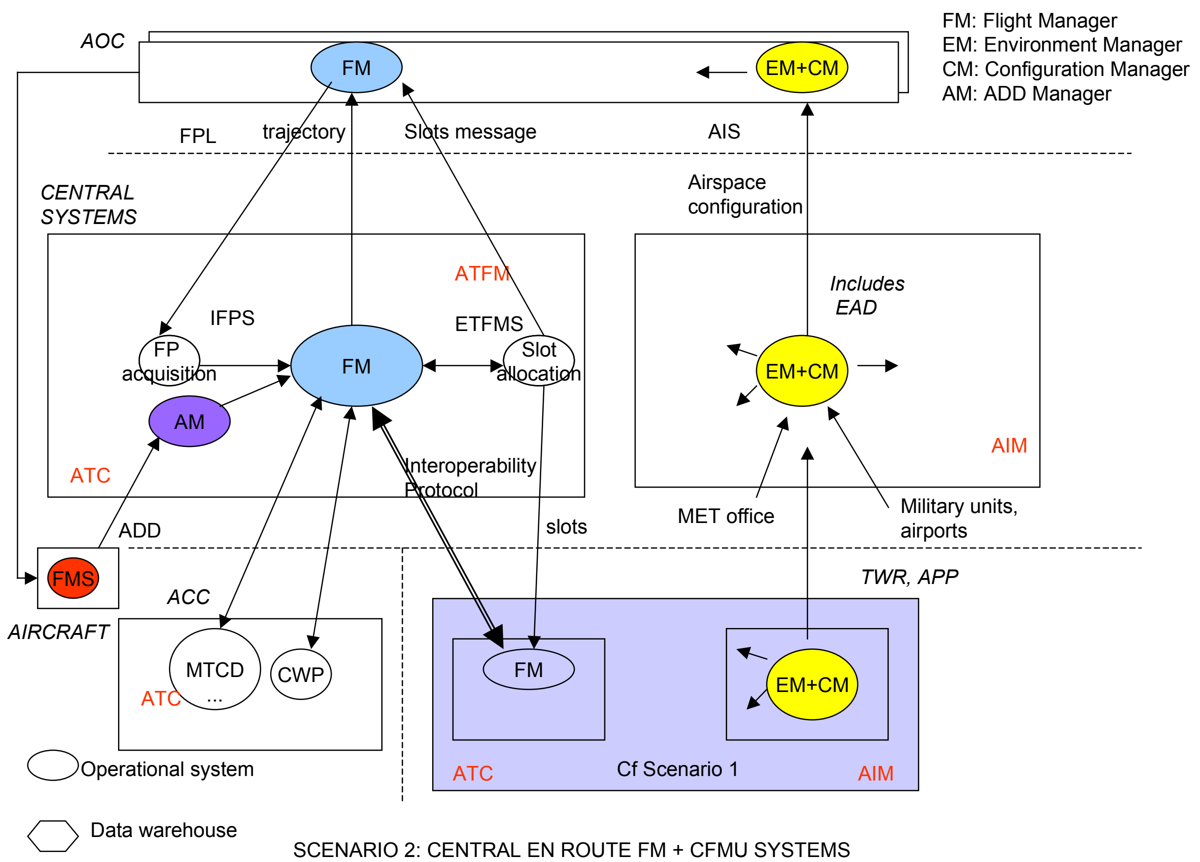
Inside an ATSU, a distributed and modular architecture with standardised interfaces is adopted.

[70] An ATSU is responsible for a geographic/functional area (Area of Responsibility) but is concerned with a larger area in order to do its job correctly (Area of Interest). It uses systems, which have the right of creation/modification (ownership) in their Area of Authority. An Area of Authority can cover several Areas of Responsibility.

ETFMS (phase 2) provides "a complete picture of predicted traffic": this view could be less accurate and less frequently updated than the view of each ATSU. No node is specially devoted to give a European-wide FD picture.

Options: the AIP data are under the responsibility of states. They are usually managed at a national level (sovereignty reasons). This management could also be delegated to a central unit (e.g. for not yet equipped countries). For these countries, the central EM would become an "operational system" and local AIP operators use client workstations connected to this central system. This is actually an EAD option.

SECOND SCENARIO: Central En-route Flight Manager + CFMU systems



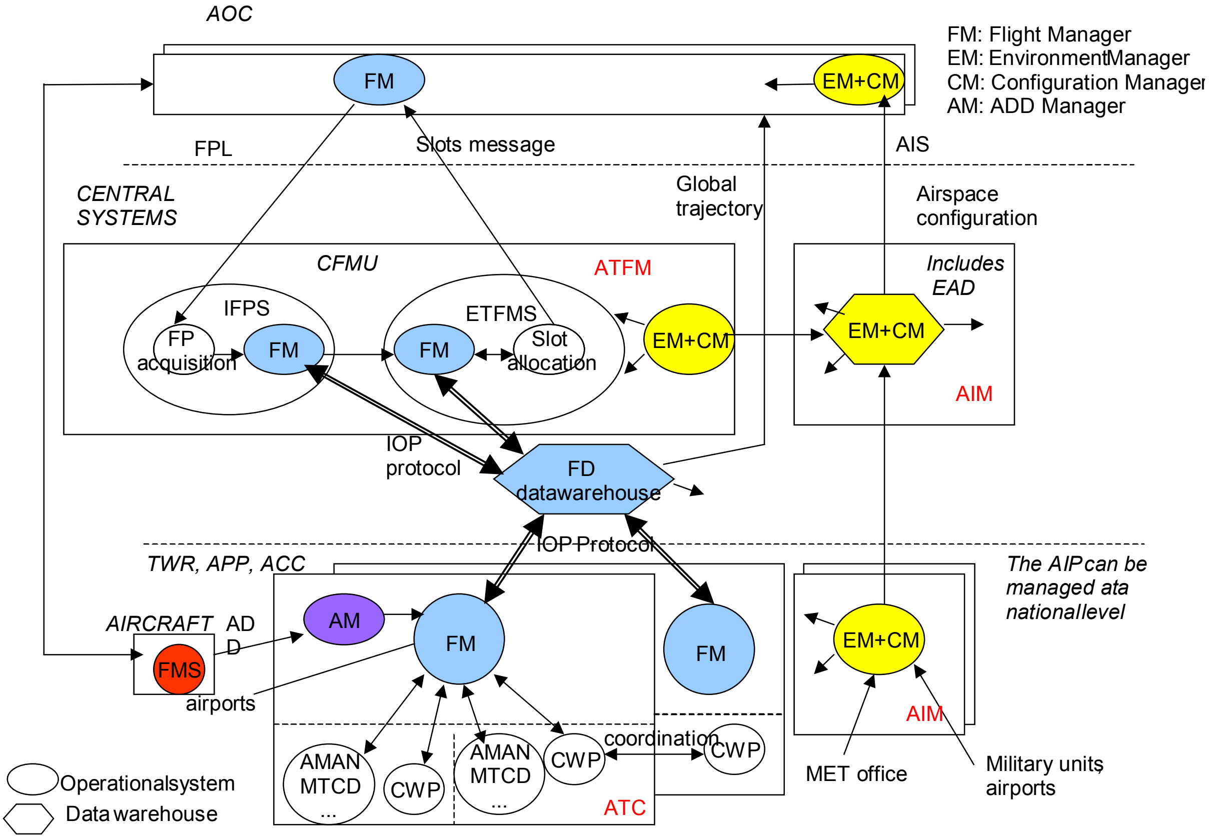
SCENARIO 2: CENTRAL EN ROUTE FM + CFMU SYSTEMS

The consistency is obtained through the centralisation of Flight Management, Environment Management and Configuration Management for the en-route airspace of the whole ECAC region. For terminal airspace, the scenario is similar to scenario 1). The en route Flight Management is strongly connected with the initial flight data processing and with the slot allocation process. There is a unique view of the flight for the en route part, which can be delivered to external systems as well as the environment and configuration data.

The architecture may be physically distributed over a few sites for the sake of dependability and for load sharing in normal operation. There could be several ACC FM nodes, each one being responsible for one fraction of the traffic, but for the whole trajectory of flights (otherwise, this would be equivalent to scenario 1). The slot allocation process, central by nature, would be located in one site, with other sites as possible back up.

The working positions could be located in several centres. The tactical tools are co-located with the CWP, with clear interfaces with FM. However, the high number of current control centres is significantly reduced.

THIRD SCENARIO: Distributed flight data servers + CFMU



SCENARIO 3: DISTRIBUTED FD SERVERS + CFMU

In this scenario, the notion of ECAC-wide Flight Data continuity is introduced. The airspace is divided into Areas of Authority (AoA), each of them devoted to a FM which is a node participating to the provision of the continuity service. Each FM calculates the trajectory in its AoA.

For providing ECAC-wide FD, especially the trajectory of a flight, a merging and/or aggregation of partial data, provided by each FM has to be performed. The responsibility for performing this aggregation can be:

- Either distributed over the FM nodes, one of them taking the responsibility of requiring the partial data to other FM, and then merging those partial data into a consistent data set, including trajectory segments concatenation.
- Or centralised in a dedicated system like the data warehouse depicted on the figure.

The main difference between those options is that in the distributed approach, each FM shall be able to perform the required data fusion and ask peer FM for complementary data, whereas in the datawarehouse case, there is a dedicated node that does not interfere with local FD processing. In addition, the datawarehouse would not re-compute any data, but apply merging and aggregation rules on provided partial data. It is assumed that a sufficient level of interoperability between FMs guarantees that inconsistent partial data are unlikely to be transmitted to (or retrieved by) the datawarehouse.

In any case, the flight data computation location is transparent to clients. Client ask for a global service that returns a unique and complete data set including either or both the flight script and the trajectory for a flight.

The FD data warehouse may be physically distributed over a few sites for the sake of dependability and for load sharing in normal operation.

The tools and other functions connected with the FM are highly modular with standardised interfaces. According to its AoA, the FM could be local or regional.

There are two principal differences when compared with scenario 1:

- A trajectory continuity service is provided to FD users across the ECAC area. In other words, the AoI of a client system is not restricted by the FM AoA to which its is connected.
- The whole trajectory is calculated by one single system which handles potential consistency issues for the client. (In scenario 1, the client system has to perform data fusion itself)

YOUR PREFERED SCENARIO

1. Which scenario do you prefer ?

☐ Scenario 1 ☐ Scenario 2 ☐ Scenario 3

with the following amendments:

____

____

2. Which organisation would you prefer to see entrusted with each of the following tasks (put a mark or give a comment in the selected cases: lead, participate, validate…) ?

	Eurocontrol	State(s)	Individual Air navigation Service provider	Several Air navigation Service providers	Industry manufacturers, service providers	Airlines	Other (Eurocae, ICAO, EC…)
Definition of operational concept - general rules (ex EATMP OCD) - local customisation							
Definition of global requirements (ex EATMP URD)							
Definition of the global architecture (ex EATMP overall architecture)							
Specification of inter-cluster[71] interfaces							
Standardisation of inter-cluster interfaces (make clear: mandatory/voluntary)							
Definition of local architecture (ex: internal to an ATSU)							
Definition of components requirements							
Specification of intra-cluster (= local) interfaces							
Standardisation of intra-cluster interfaces (make clear: mandatory/voluntary)							

[71] See definition of clusters in the annex.

Procurement of AFTM/ATC FDP components							
Development of AFTM/ATC FDP components							
Integration of AFTM/ATC FDP components							
Exploitation of AFTM/ATC FDP (Technical)							
Utilisation of AFTM/ATC FDP (Operational)							
Definition of flight data access rights							
Distribution of flight data							
Owner of the flight data							

with the following comments:

____

3. Please indicate below the reasons of your choice (underlying the most important ones).

OPERATIONAL

☐ contributes to de-fragmentation of Air Traffic Management (airspace and systems) in Europe

☐ meets the requirement for “provision of European-wide correct, consistent, up-to-date and easily available Flight Data”

☐ eases functional evolutions and supports new tools

☐ takes into account the “local” specificity

☐ leads to a standardisation of operational procedures

caters for the needs of ☐ airlines (AOC), ☐ military users ☐ military control units

☐ allows for a selective (hierarchical screening) processing of flight data and environment data

☐ allows for a common processing of the flight data and environment data

is good ☐ for safety ☐ for security ☐ for efficiency

TECHNICAL

☐ is technically feasible

☐ respects performance requirements (eg response time, capacity)

☐ allows for an easy transition from legacy systems

☐ allows for/ is dependent of/ a good level of standardisation and services definition

is good ☐for dependability ☐ for maintainability (correction, evolution, adaptation)

☐ is consistent with current R&D activities

COSTS

minimises ☐specification costs ☐ development costs ☐ transition costs

☐ integration costs ☐ system operation costs ☐ maintenance costs

☐ ATC operation (including training) costs

☐ allows for a clear partitioning of the costs between stakeholders

OTHERS

☐ can be accepted through a wide consensus by the stakeholders

allows for competition between ☐ systems providers ☐ service providers

allows for a clear definition of ☐ data ownership ☐ data confidentiality

☐ responsibility/liability ☐ the respect of sovereignty rights

☐ allows for the control of flight data by each ATSU (local unit)

☐ allows for the delegation of the management of flight data (to a regional or central server)

☐ is consistent with the role which is or must be devoted to Eurocontrol

☐ is consistent with the role/responsibility of the interviewed stakeholder

☐ is consistent with the commercial interests of the interviewed stakeholder

☐ is socially acceptable

☐ minimises risks: ____

Comments:

____

4. If the flight manager has to be centralised in more regional or central units, do you think that the following components/functions must be centralised too:

☐ Trajectory predictor

☐ Flight Plan monitoring

☐ Correlation

☐ Co-ordination

☐ Aircraft Derived Data Manager (part trajectory consistency)

☐ Medium Term Conflict Detection (MTCD)

☐ Short Term Conflict Manager (STCM)

☐ Surveillance Manager

☐ CWP

☐ Others:____

5. Do you need access to Europe-wide correct, up-to-date and consistent flight data information? If, yes, it is for:

☐ essential ATC operational purposes

☐ ATFM operational purposes

☐ AOC purposes

☐ military purposes

☐ non-operational purposes like added value services, third party publication, etc. (make clear)

INSTITUTIONAL ISSUES

Below we identify certain policy questions about the future structure of Flight Data Processing systems and services in European airspace. Alternative statements of position are listed under each issue. Please indicate which statement best expresses your position (or replace or expand the statement by suggesting a further alternative).

6. How efficient are current institutional and organisational arrangements? By "institutional" we mean all the arrangements made in relation to institutions established by international conventions (ICAO, Eurocontrol), and by the European and national legal constructs. By "organisational" we mean all the additional ad hoc solutions to various co-operation and co-ordination issues to be put in place when implementing and deploying a specific programme.

☐ Current institutional co-ordination among the individual FDP system operators works quite well and can be expected to adapt to the evolving needs of the market.

☐ Current arrangements are becoming inefficient. Both the technology of data gathering and the demand for FDP services require a progressive scaling-up and regional co-operation in planning, procurement and eventual operation.

☐ Current arrangements are wasteful and produce unacceptable inconsistencies. For the EU states at least, barriers to cross-border co-operation in the establishment and provision of services, if any, need to be rapidly removed and common performance standards established and enforced.

☐ None of (or in addition to) the above. The following institutional approach to improve efficiency of FDP services is required:

____
____

7. Does today's system contain barriers to enhanced co-operation?

☐ We perceive neither legal nor significant policy barriers to enhanced co-operation in the development and provision of FDP services at European scale. Present instruments of policy are sufficient. Constraints if any are technical and economic and can be debated in current fora.

☐ European institutions need to build a new framework of encouragement that will stimulate joint actions and pragmatic, flexible solutions based on stronger partnership at all levels -- among manufacturers in the development of interoperable standards; among Asps in specifications and procurements; among Aircraft Operators in data development and exchange; etc.

☐ European institutions need to set clear standards that will eliminate local barriers if any and facilitate the development of a modular FDP functionality, that provides timely and cost effective services that enable ATM systems evolution and implementation of the Single Sky.

☐ None of (or in addition to) the above. European policy needs to address removal of the following barriers to co-operation and/or focus also on increasing competition

____
____

8. Are new joint policies or rules for the standardisation and specification of a new FDP system or systems required?

☐ No; keep the status quo. The persistence of complex operational requirements specific to each control area suggest that existing ICAO standards governing flight plan data, ADS flight profile data and the Eurocontrol OLDI-SYCO standard can ensure an appropriate level of interface interoperability for the foreseeable future.

☐ Yes; we should establish core standards to ensure basic common levels of FDP functional performance for all airspace segments (airport, TMA, en route).

☐ Yes; we require not only a basic but an expanding level of joint performance standards to facilitate a higher common level of service provision and respond to new and growing operational needs.

☐ Yes; in fact, formalised standards in the form of Minimum Operational Performance Standards (MOPS) binding on manufacturers as well as ATSPs (and possibly including specification of standardised modules) must be defined and compliance enforced by regulators.

☐ None of (or in addition to) the above. New standardisation requirements should take the following form:

____
____

9. Should European institutions establish new joint procurement policies or rules?

☐ No, keep the status quo. Each ATSP has the best overview of total FDP requirements; therefore, it should continue to issue calls for tendering for localised procurements based on local specifications.

☐ Yes; we need co-operative modular specification. Working together, ATSPs should agree standardised modules that would lead to sets of common, core specifications, while still enabling local operational control as well as certain customisation to address specifics of the operating region.

☐ Yes; indeed a centralisation of specification, putting an external third party in charge of it on behalf of all the European ATSP is needed (this approach can be seen as an “outsourcing” of the specification phase). Technical procurement specifications should be developed by a competent European body (Eurocontrol) or by a selected contractor based on performance standards established by regulatory proceedings (ENPRM).

☐ None of (or in addition to) the above. Procurement policies and rules should be reformed as follows:

____
____

10. Should the European Commission act to reform the framework of today's FDP market?

☐ No, keep the status quo. The current situation, despite fragmentation of supply and possible diseconomies of manufacturing scale, has kept the FDP market open to competition, which may be useful as an incentive to innovation.

☐ Yes; we need consolidation. The EU should act to encourage emergence of a smaller number of FDP systems possibly procured by a smaller number of ATSPs from a reduced number of manufacturers in order to end wasteful fragmentation and realise the Single Sky.

☐ Yes; in fact we need a central system. A single, core FDP system can best serve the European market, eliminating data inconsistencies and promoting application of new technologies. This does not exclude local customisation, which will never disappear. Moreover, central design, specification and even modular procurement does not preclude competition for the market; for example, operations could be outsourced through franchise competition.

☐ None of (or in addition to) the above. Steps should be taken to restructure the market along the following lines:

____
____

11. Will the establishment of future FDP systems also require new forms of regulation in the safety area?

☐ No, such new regulations basically are not needed. For example, FDP will never be a safety-critical subsystem; thus, regulation here is not required.

☐ Yes, though not in the form of operational safety monitoring. Required will be compliance certification processes to increase interoperability and seamlessness of FDP services.

☐ Yes; increased operating densities in European airspace will increase requirements for flight data accuracy, integrity and timeliness that lead to need for tight monitoring from a safety standpoint -- including the production and assessment of global safety requirements bearing on FDP services.

☐ Yes; future European FDP systems and services will require a full-fledged certification process including elements such as: Safety specification reviews; a type approval process for FDP systems; an operational certification process for ground services; as well as end-to-end certification of flight data coherence; etc.

☐ None of (or in addition to) the above. Needed safety regulation can be provided by:

____
____

12. Should we establish new forms of ownership and operation of FDP service provision?

☐ No; direct accountability by each ATSP for the provision of needed FDP data to its ATC and other users continues to make the most sense.

☐ Yes; while ATSPs should retain individual or shared ownership rights over the FDP system, efficiency and technological modernisation require co-operative, scaled-up and possibly "unbundled" FDP service provision by a reduced number of providing units in larger blocks of airspace.

☐ Yes; in fact, a single data bank operation (with redundancy provided by a back-up location) should be established by Eurocontrol subject to EU and Member State guidelines and be either operated by Eurocontrol services directly or by a competitively selected franchise provider.

☐ None of (or in addition to) the above. The preferred form of future FDP service provision should embody the following characteristics:

____

____

13. Are new rules on access to and protection of data needed?

☐ No. Safe separation of traffic operating under IFR rules in public airspace means that actual and intended positional information must be freely available for authorised professional use in connection with the safety, security and expeditiousness of air traffic management.

☐ Perhaps. Especially in the case when FDP services are provided on a commercial basis, the dissemination of flight data might have to be regulated in such a way that the rights of companies and individuals to commercial confidentiality and privacy are respected, especially when that information is to be used for non-operational purposes.

☐ Yes, probably. Especially if a central data bank is established to provide single source FDP information to all interested parties, formal rules must be developed to govern its policies of acquisition and dissemination of information.

☐ None of (or in addition to) the above. The following particular FDP considerations should be applied to the development of EU data access and protection rules.

____

____

ANNEX: DEFINITION OF FDP

We follow here the logical decomposition used in the EATMP Overall architecture which is segmented into domains that correspond to stakeholders' activities: ATM/CNS, Airports (air side), Aircraft (avionics), Airline Operational Cells (flight planning/dispatch system). In this logical architecture, "components" store data and provide services to other components or users. The so-called "cross domain components" are the components that are subject to various allocations to stakeholders' systems. The cross-domain components are:

- The "Flight Manager" (FM), which is responsible for provision of a validated, accurate and up-to-date view of flight information. The ATC Flight Manager is a version of the cross-domain Flight Manager augmented with SSR code management and flight plan conformance monitoring. The main data items stored by the Flight Manager are the ICAO Flight Plan, the ATFM or ATC constraints, the flight script (combination of flight plan data and constraints), the trajectory (sequence of 4D points), and the distribution list (set of flight data users).
- The "Environment Manager" (EM), responsible for both the periodic production of aeronautical information and the real time access to those data. Main data items: geographical data, airspace organisation, sectorisation data, aircraft performance, and meteorological data.
- The "Configuration Manager" (CM), in charge of providing the current ATM configuration (actual state of dynamic airspace items, sectorisation) and the workload of the sectors.
- The "ADD Manager" (Aircraft Derived Data) (AM), which is a utility component that collects and maintains the navigation state vector and other airborne parameters for the benefit of other components.

The Overall Architecture allocates "clusters" of components to domains. Those clusters contain specific components and instances of cross-domain components. The table below illustrates this allocation. Greyed cells mark cross-domain component allocation. What we call "FDP", in a broad sense, is marked with a border in bold. It covers the Flight Manager in ATC and ATFM domains, the tools linked with flight data (FD) in ATC, including the ADD Manager and the necessary Environment and Configuration data Managers.

Components	AOC	Aircraft	Airports	ATFM	ATC	CNS
Air Data Acquisition						X
Air Surveillance Server						X
Ground Data Acquisition						X
Ground Surveillance Server						X
Mobile Comms Manager						X
Air Traffic Flow Manager				X		
Load State Manager				X		
Configuration Manager (CM)	X			X	X	
Environment Manager (EM)	X	X		X	X	
Flight Manager (FM)	X	X	X	X	X	
Correlation Manager					X	
Arrival Manager (AMAN)					X	
Departure Manager (DMAN)					X	
Medium Term Conflict Detection (MTCD)					X	
ADD (aircraft derived data) Manager (AM)	?				X	X
Short Term Conflict Manager (STCM)					X	
Controller Workstation Manager (CWM)					X	
Flight Planning	X					
Ground Operations Manager (Gate/stands)			X			
Infrastructure Manager			X			

ANNEX D: TECHNICAL ARCHITECTURES

Technical architectures reflect the potential technical solutions for managing European-wide flight data, and accessing flight data services, with data and service providers' location transparency.

There are several technical frameworks that can be envisaged for data sharing and/or remote service requests. In this section, we make a brief survey of system integration factors and of several recognised integration solutions that are deemed promising for the ECAC-wide Flight Data provision: message brokers, application servers and data warehouses.

Annex D.1. System integration

Technical frameworks for system integration depend on three major driving factors:

- The capability to conform to an integration standard.
- The considered integration level in the overall system's structure
- The control policy over the integrated system

The capability to conform to an integration standard is a compound property that mixes development policy and the need to reuse legacy systems:

- High capability: Two base cases determine the range of possible mixes:
  - The system is mostly composed of newly developed components. In that case, a component-based development approach is possible and a standard like CORBA, COM+ or EJB can be adopted.
  - The system is a legacy system that can be re-engineered into a component-based architecture or wrapped to behave like a component, providing an integration interface according to one of the above mentioned standards.
- Low capability: The system is a legacy system that cannot be economically re-engineered nor wrapped to conform to one of the integration standards. In that case, integration will rely on other integration technologies like message brokers.

The integration levels usually considered are the following:

- Integration within a computing node. At this level, there is one homogeneous computing environment (e.g. operating system, inter-process communications, shared memory).
- Integration between computing nodes within a given unit. At this level, there are solutions for integrating applications over a LAN in spite of heterogeneous computing nodes. Technologies like CORBA and EJB are well suited and support synchronous request/response between processes that run on different nodes as well as asynchronous event notification.
- Integration between units. Integrating computer systems scattered among several units is more difficult. Generally, the systems in the units are themselves distributed systems. They use different technologies and have been developed according to different standards. This integration level is the same as the "B2B" level of business data processing. Integration technologies are rather based on message brokers.
- Integration with end-users. This last level adds the variability of users' needs to the previous level. This means that the same "server" application must support many flavours of client request, with fast changing requirements. This integration level is the same as the "B2C" level of business data processing. The trend is to use Web servers as font-end to serve end-users.

The control policy is related to the overall behaviour of the integrated system. The control policy indicates how a full operational process is implemented by the supporting system:

- Centralised control. In that case, there is one explicit "workflow manager" process which takes the responsibility of controlling the overall execution of each operational process. The operational process is split up into sub-processes that are executed by several co-operating sub-systems, under the control of the workflow manager. This control policy is one of the key feature of Enterprise Application Integration (EAI) solutions, implemented by a message broker, in a broader sense than the older message-oriented middlewares.

- Distributed control. In that case, each process is responsible for a part of the overall operational process and passes the control to the next process, without being aware of the overall process execution. This kind of control is implemented for instance by one-to-many "publish an subscribe" mechanisms.

Annex D.2 Message brokers

Enterprise Application Integration (EAI) is a "hot topic" in the data processing area. There are as many definitions as EAI experts. Fortunately, there are some common points that characterise the technical framework. EAI is conceptually simple, and targets the integration of legacy systems by minimising the adaptation of those systems. In the integrated architecture, the legacy systems are all connected to a common node, called the "message broker", in a kind of "hub and spokes" pattern. The message broker solves the discrepancies between systems in terms of technologies and standards and provides additional system-wide services. To be short, it encompasses three layers, from bottom to top:

- Communication management. This layer handles all conversion between heterogeneous protocols, physical data formats, etc.
- Message routing. This layer performs guaranteed message delivery between nodes according to routing rules stored in the broker. Data conversion and adaptation between application-level formats are also performed.
- Workflow management. This layer implements the central control policy. The global services provided by the integrated systems is managed by a set of operational process models stored in the message broker. The message routing rules implement the process flow model.

The main advantage of the message broker solution is that the impact on integrated systems is minimised. However, the message broker is a single point of failure of the integrated system and must be implemented with an high availability technology.

Figure AD1 illustrates the message broker concept.

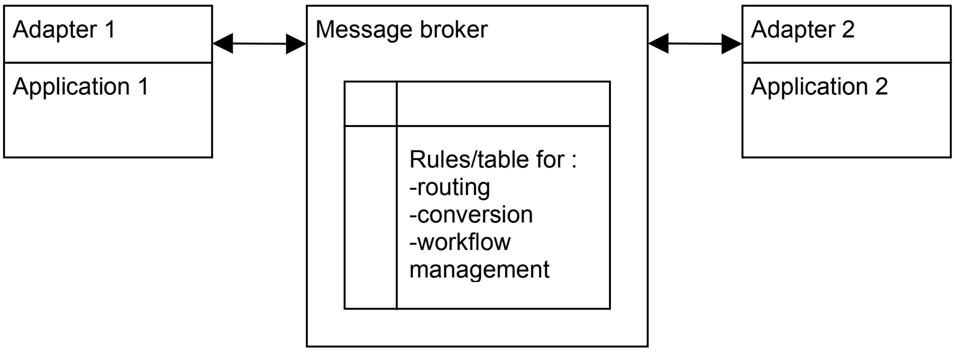


Figure AD.1: Application integration through a message broker

A short ATM scenario illustrates the potential role of the message broker. Figure AD2 illustrates the dialog between FM components located in two adjacent ATSUs, a Central Flow Management Unit, and an AOC, as it would take place with the current OLDI et IFPS/TACT/ETFMS messages. ATSU 1 modifies the flight data, informs the next ATSU with a REV message that is supposed to replace a previous ACT message, informs the CFMU with a AFP message. We assume that the impact on the flight is notified to the AOC by ETFMS for instance with a "XXX" message (maybe the point profile)

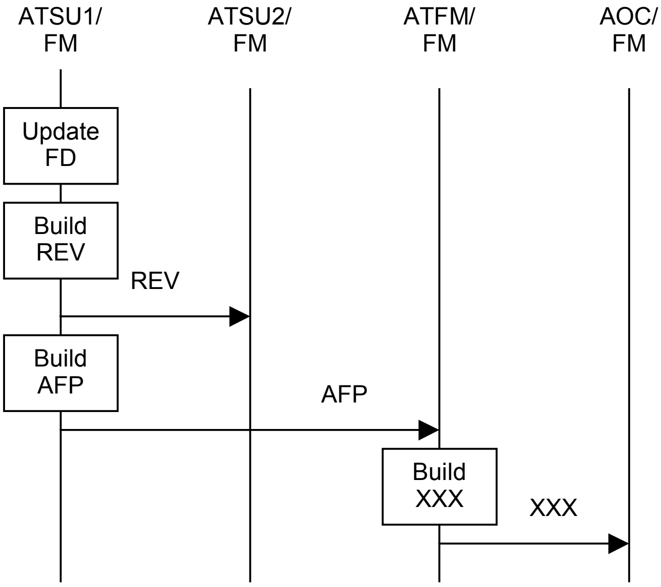


Figure AD.2: System to system message-based communication

The introduction of a message broker would give the scenario depicted by Figure . The determination of the addressees of messages as well as the decoding and encoding of messages would be handled by the broker. The broker would also guarantee the delivery of messages and check that the whole operational scenario is completed.

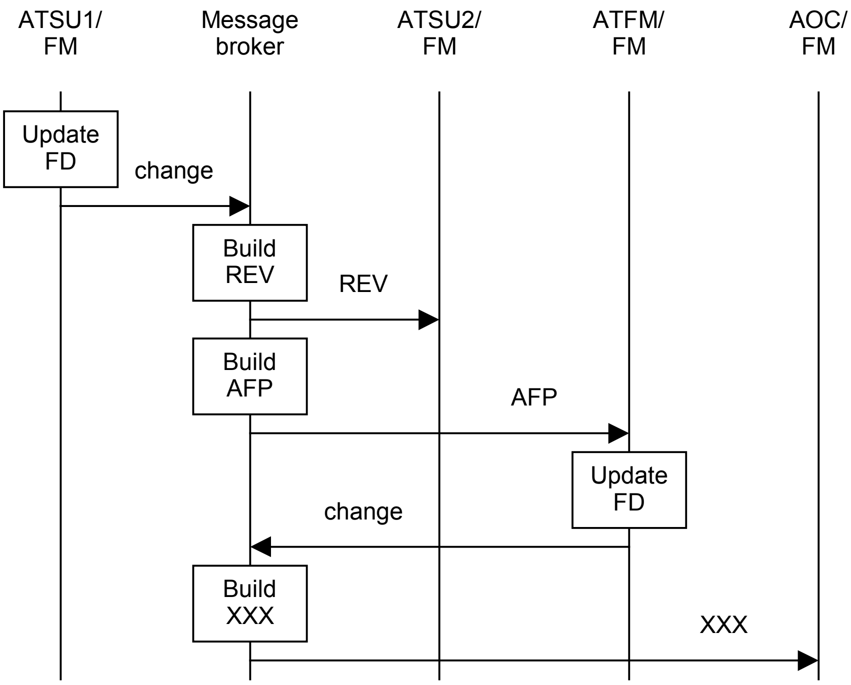


Figure AD.3: Communication through a message broker

Annex D.3. Application servers

Application servers are the core of the three-tier client/server (C/S) architectures. The Gartner Group has introduced the well-known decomposition of C/S applications into three logical layers: the data management layer (files, databases), the application logic layer (algorithms, business rules) and the presentation layer (HMI, user interaction).

In the data-centric two-tier C/S architecture, the data reside in a data server, generally based on a (Relational) Data Base Management System ((R)DBMS). The application logic is hosted by client applications that also handle user interaction and are consequently called “fat clients”. This 2-tier architecture is well suited when clients are PC-based applications that access one single shared database. This architecture does not scale up easily when several applications are needed at once with accesses to several data-bases.

Application servers incorporate most of the application logic, leaving the client with the user interaction responsibility only. This allows developers to centralise the application logic in one (or a few) place(s) and benefit from integration technology to cope with multiple data sources (database multiplexing, transaction processing monitors) and multiple communication protocols.

Application servers can co-operate to provide a global service, one server becoming the client of another server until the latter completes the requested service. Co-operation between application servers can use either synchronous or asynchronous communication mechanisms.

Moreover, the emerging “container” framework as implemented by Enterprise Java Beans (EJB) or as specified by CORBA 3, is an enhanced version of the 3-tier architecture whereby application servers are replaced by components embedded into containers that provide generic middleware services to the components. The AVENUE project has demonstrated the implementation of an ATC real time simulation system in a container-based environment.

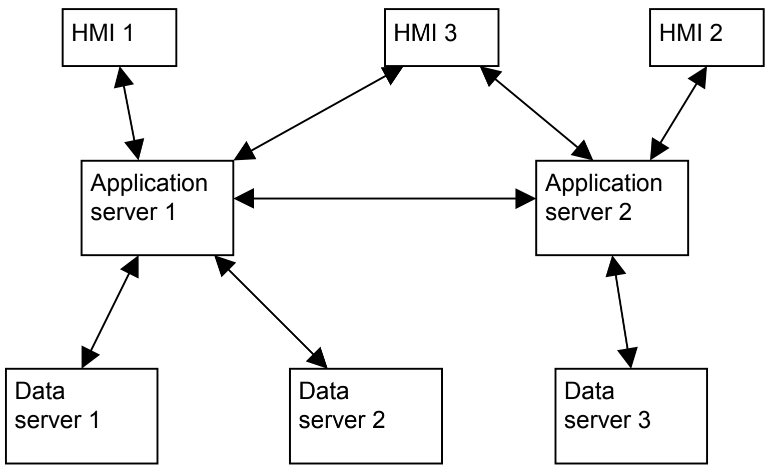


Figure AD.4: Three-tier architecture

A direct implementation of the EATMP overall architecture would consist of one application server and one (or more) data server per logical component.

Annex D.4. Data warehouses

A data warehouse is a solution to data integration in a restricted sense. Corporate data warehouses provide enterprise-wide data to decision support systems in large business organisations. In such architectures, a data warehouse is a centralised database that retrieves operational data from local databases, consolidates the data and presents a new consistent view of the operational data needed by the users. The data retrieval by-passes the application servers and relies on specific tools for extracting, transforming, moving and loading data (so-called ETML tools).

A data warehouse is often developed after releasing several stand-alone, or loosely coupled local systems, to provide harmonised common information to decision makers.

One key feature is that data warehouses are mainly read-only databases, otherwise, data consistency would be impaired by concurrent data updates in the local operational databases. Another feature is that the amount of data involved in decision support tasks is generally far larger than what is used by transactions in operational database systems. This has a significant architectural impact on the design of a data warehouse.

In addition, technical problems stem from the consolidation of heterogeneous data. The data warehouse database schema has to integrate subsets of the schemas of all operational databases. Each operational database implements a formalised view of the real world. Operational databases overlap for some aspects of the real-world, and in the best case adopt semantically consistent models, but syntactically different representations for those aspects. Therefore, filtering and merging the data from all the operational databases into a single model is a major issue.

Another limiting aspect is that data warehouses are generally updated on a periodic basis since they access directly the operational databases. This does not mean that the retrieved data are inconsistent: They are in the last stable state which results from the last transactions issued by the application servers. This means that a data warehouse may miss a part of the data update history if the sampling period is too long.

Keeping in mind that services are limited to decision-making support, a data warehouse provides a single specified interface for connecting client systems. If clients need to update operational data, they have to connect to operational systems directly.

Figure AD.5 illustrates a data warehouse that integrates data from three operational databases. Users perform transactional processing on operational data through HMI 1 and 2 and applications servers 1 and 2 respectively. Users of the data warehouse issue queries to the data warehouse but cannot access the operational databases. This architecture is well suited for a layered organisation including for instance a central planning function, using the data warehouse as a data source for determining objectives from the current state and history and local process control functions that monitor the operations and provide feed-back to the planning function.

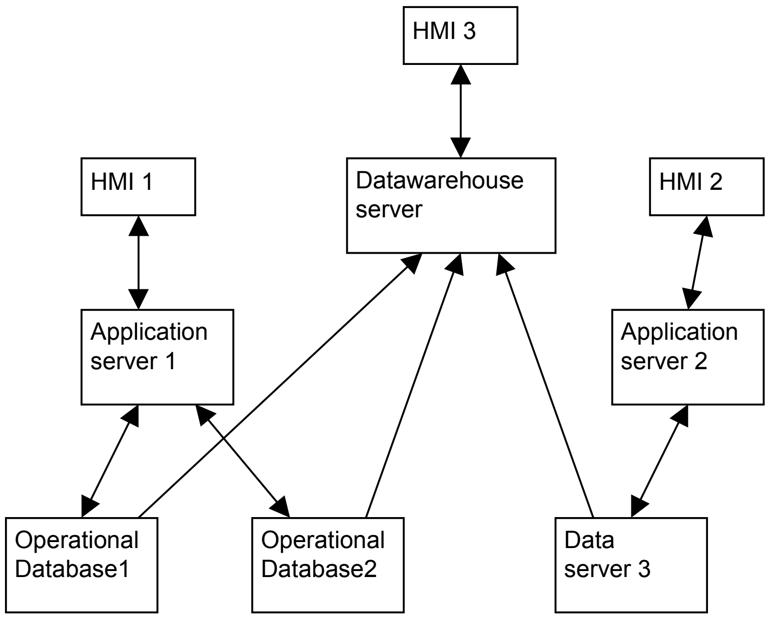


Figure AD.5: A distributed architecture with a data warehouse

Annex D.5. Data consistency management

Data consistency has various meanings.

Annex F provides a detailed discussion of the operational view of data consistency for ATM. The viewpoint presented here is the technical one. The consistency problem is also limited to the consistency between persistent data of separate systems in a distributed architecture, for instance, a flight profile held by the FMs of two separate ATSUs[72].

In technical terms, data consistency is a property of multiple copies of the same data item. However, in distributed systems, there are several flavours of data consistency and we have to be more specific. Consistency is expressed for: a data item X; its copies X1, X2,… and operations on data items: read and write, which respectively reads the value of X and assigns a (supposedly) new value to X. The successive values assigned to X are denoted V1, V2, etc…

The strict consistency is such that whenever some user writes a copy Xi, assigning the value Vk to Xi, all users can “immediately” read any copy Xj and retrieve Vk. Write operations are mutually exclusive on a copy (no two writers can write the same copy at the same time). Concurrent read operations are permitted.

Strict consistency is not achievable in distributed systems, where inter-process communication or network latency generates delay for propagating the value to all copies.

The usual way to cope with data consistency consists of several protocols that satisfy expected properties.

One catchall and practical approach is to use transactional processing. Transactional processing is supported by database management systems (DBMS) in a homogeneous database environment. It is also supported by transaction processing monitors (TPM) that

[72] There are many data consistency issues in a computer system owing the “memory hierarchy”, which comprises for a computing node: the internal processor data cache, the external caches (per processor, shared by processors), the core memory (DRAM memory), the disk cache in core memory, the disk memory, let alone the magnetic tapes…

allow mixing several database products. Transactional processing satisfies the so-called ACID properties:

- Atomicity: One transaction is either fully executed or not at all (All-or-nothing)
- Consistency: One transaction moves the state of the database from one consistent state to another consistent state.
- Isolation: One transaction is executed as if it was the only operation performed in the system at a given time.
- Durability: The effect of the transaction is made persistent.

With this respect, DBMS adopt 2-phase locking and 2-phase commit protocols and auxiliary mechanisms (Log files) to cope with various failure conditions. The cost of the protocols is expensive in terms of latency.

Assessment studies for the use of relational DBMS in ATM have been conducted several years ago[73]. The conclusion was not satisfactory, due to performance shortfalls (response time and throughput). However, drastic progress has been made since this early work, both in hardware and in DBMS technology. The assessment should be done again, owing to the potential advantage of using proven commercial solutions.

Besides the technology itself, there has been a lot of discussion about the need for transactional consistency and the possibility to adopt a weaker consistency. A weaker consistency means here that at a given time, several FD users would see different values for the same data, because copies are not tightly synchronised. The requirement is made that synchronisation takes place in a short period of time. This refers to the time consistency attribute of the quality of service: that is the time interval between the update of the first copy and the update of the last copy for a given write operation.

Operationally speaking, it makes sense that the downstream ATSU is not so much concerned by a time deviation of the flight. Currently, the time estimate at the co-ordination point (COP) is transmitted when the ACT message is sent, that is about 10 minutes before actual transfer.

However, this is probably a short-term view of the problem, rooted in the current practice. More accurate medium term prediction (e.g. cross border MTCD and AMAN) would probably raise the expected quality of service.

Transactional processing and DBMS have been deemed “overkill” for flight data management, and there exist indeed less demanding protocols, that provide weaker consistency. Unfortunately, those protocols are not integrated with desirable properties like concurrency control, data persistence and recoverability. This means that a specific design must be made for an integrated solution. This is likely to be more costly and less effective, let alone the fact that new functions might well require more stringent consistency later.

The trade-off is between COTS solutions that are not deployed in the current systems (and not required so far in the planned programmes), and in-house solutions that are more costly and do not provide the same quality of service.

Annex D.6. Support to scalability

Scalability is deemed “supported by the technology” if there is no need to modify the source code of applications when the “size of the problem” increases[74]. Size here can be expressed by the number of flights simultaneously present in the database, the number of controllers’ transactions per minute, the frequency of periodic monitoring processes, etc.

Two main factors are considered:

- Storage capacity: both resident data storage and transient data storage.
- Processing capacity: expressed by throughput and response time

[73] A study was conducted by Hugues for Eurocontrol in 1994.
[74] There are two related views of performance enhancement in a system: speedup and scale up. For a given system, when doubling the resources, we can have the resource usage divided by 2 (speedup) for the same workload, or the resource usage kept at the same level while doubling the workload (scale up).

Current FDP systems are often based on mid-80s designs, and use mini-computers that come to an end. Replacement programmes target client/server architectures that more easily support scaling up by node duplication and computing resource allocation.

However, when FDP systems are re-hosted on modern architectures, scalability might be impaired by the software architecture. For instance, an application written like a large single process will need to be re-engineered to benefit from scalability solution provided by system software and hardware.

The support to scalability provided by the technology is two-fold:

- Symmetric multiprocessor systems (SMP). One SMP provides increased computing power and high storage volume in a single computing node. Conceptually, in a SMP, there are several processors that share a memory, I/O controllers and the mass storage. There is one single operating system instance in charge of managing the node. To benefit from SMP, one application process shall be multi-threaded, allowing concurrent threads to run on separate processors. The advantage of SMP is that the speedup factor (or scale up factor) is linear in the number of processors for a small number of processors[75]. The main disadvantage is that the operating system is a single point of failure.
- Clusters. A cluster couples separate computing nodes over a high performance network. The cluster favours high availability, but raises problems for distributing a system over the network, especially when a database is involved.

A database that has both an increasing size and an increased transaction rate can benefit from the scalability in three different ways:

- The “share everything” way: The database is implemented on an SMP. Transactions are allocated concurrently on the processors, or decomposed into separate sub-transactions.
- The “share disks” way: The database is implemented on separate SMP that share their disks through a high performance network.
- The “share nothing” way: The database is implemented on separate SMP, that communicate by message-passing over a high performance network

All these architectures expect the geographical proximity of computing nodes, for ensuring low network latency time.

Annex D.7. High availability

Annex D.7.1. Intra-unit availability

From the technical viewpoint, high availability involves both hardware and software availability. In a three-tier architecture, each tier is implemented by computing nodes that include hardware and software.

With respect to the I2FDP scope, we discard the presentation tier, corresponding to the controller HMI. This does not mean that there is no high availability requirement expressed for the CWP, but, even if CWP failure is not desirable, one given CWP is not a single point of failure in a control room. There is a built-in redundancy in the position and between positions in the room.

On the contrary, surveillance and FDP systems are generally centralised. They currently embody the two other tiers: application logic and data management. In a modern three-tier architecture, assuming that data management is separate, with recovery mechanisms similar to what is proposed by DBMS products, a high availability system can be implemented by a cluster architecture.

Separate nodes in the cluster cater for node hardware failure.

Regarding software failures, as usual, we consider separately Bohrbugs and Heisenbugs. Bohrbugs are those software defects that cause “deterministic” failures in the sense that they can be replayed in a systematic way by appropriate testing. Conversely, Heisenbugs are those

[75] The linearity is degrading by concurrent accesses to shared resources, including data.

defects that cause “random” or “transient” failures that cannot be replayed in a systematic way by testing.

On the one hand, in a cluster where application servers are replicated over several nodes, Borhbugs generally introduce common cause failures between replicated software, and the same input that makes one server crash will make another server crash as well. The only solution to avoid it is to develop and deploy dissimilar software versions (N-version programming), solution which, up to now has been considered overkill for FDP.

On the other hand, Heisenbugs are related to a transient internal state of the computing node mixing the state of the application software and the state of all system software, firmware and hardware that leads to an unexpected transition to an unmanaged state, which either “freezes” or “crashes” the application process or even the whole node. The probability of reaching the faulty state is very low, and generally, restarting the process or the node is just enough to recover the application. However, if data are shared with other processes that did not crash, data are no longer consistent between the processes. This is the main reason to adopt transaction processing, since this ensures that shared data are either all modified or unchanged upon the crash of one process.

The price to pay is the adoption of a specific programming model, based on transactions, for all persistent data shared by different applications.

Annex D.7.2. Inter-unit back-up capability

Distributed architectures are deemed more reliable that centralised architectures, because the central node is a single point of failure. However, when duplicating the central node, there is no longer an evidence of which architecture is the most beneficial. The failure modes and operational penalties have to be estimated for each architecture.

In the discussion about potential ATM architecture, proponents of distributed architecture refer to the capability of one ATSU to switch a remote system upon failure of its own FDP system.

From the technical point of view, this has some strong implications. At the present time, FDP systems are loosely coupled and exchange only very coarse grain information embedded in messages according to various bilateral protocols (e.g. IFPS to ATSU, TACT to AOC and ATSU, OLDI co-ordination). Upon failure, it is possible to re-build a flight database from an adjacent system by a bulk transfer of flight plans. This is for instance possible:

- Between IFPS and an ATSU,
- Between ATSUs inside some national systems

The recovery protocol consists in:

- Restarting the failing FDP system, with an empty flight data base
- Re-populating the flight database from adjacent systems.

It is possible to have a copy of all the flight plans in adjacent systems. It is more difficult to have those flight plans in the most recent state, if updates are not systematically notified to adjacent systems. At the present time, replicated flight data are not consistent.

However, even with new fine-grained flight data and systematic update notification, this is completely different from switching a control room to a remote flight data processing system. In a distributed architecture, with heterogeneous node systems, it seems unrealistic to have one control room switched to a remote FDP system. Adjacent ATSU should agree on back-up procedures, and implement extra computing resources to store flight data from the adjacent unit, and provide FDP services to the adjacent unit in case of FDP failure, ensuring a switching time shorter than the current time to restart the FDPS.

On the contrary, in a centralised architecture with a few replicated nodes, it is possible to have connections ready for switching from one node to another. In normal mode of operations, the nodes share the overall workload and when one node fails, the connected client systems (the proxy servers of the control rooms, for instance) are switched to another node. The data are accessible to all nodes and the computing resources are sized to permit one or more failures without impairing service continuity. This approach is illustrated by the current IFPS architecture.

Annex D.8. System integration guidelines

The range of technical solutions for integrating FDP systems can be significantly reduced, owing to the fact that FDP systems are mostly legacy systems, with no provision for easy re-engineering.

The foreseen FDPS replacement programmes (e.g. EFDP/fi) give the opportunity to implement more modular architectures, in line with the EATMP overall architecture. If standard interfaces for EOA components are specified before the development phase of new FDPS, these systems will be easier to integrate in an ECAC-wide system. A component-based development approach can be adopted and technologies like CORBA can provide the technical framework for such systems.

However, those replacement programs impact only a few ATS providers and some others have recently deployed FDP systems that cannot be reasonably re-engineered in the medium term. Those systems need to be fitted with wrappers that will implement the expected component interfaces.

Moreover, the EOA identifies FM components into AOCs, Airport and Aircraft airborne systems. Those systems are likely to adopt very different technologies. It is deemed unrealistic to envisage a tight integration of those systems.

The minimum impact to systems that either are existing legacy systems or will be developed by separate organisations with different technical options is achieved by inter-unit EAI techniques such as message brokers and data warehouses.

This means that there are probably two sets of interface standards to consider:

- One set of standards for components integrated in a cluster (like the ATC cluster), assuming that a cluster is located in one unit, more generally in one site (possibly the onboard computer system)
- One set of standards for inter-cluster exchanges, including both client/server interactions between different components, and synchronisation interactions between instances of the same logical components. This latter kind of interaction is often designated by the “interoperability” term.

ANNEX E: FLIGHT DATA DESCRIPTION

Annex E.1. Flight data model

The essence of the flight data model is to collect the prediction of the behaviour of individual flights.

The model is outlined below by a small UML class model. Potential conflicts have been included in the model, since these conflicts are based on predicted trajectories. Note that this does not imply that “conflict detection” is a service integrated in a Flight Data Processing System.

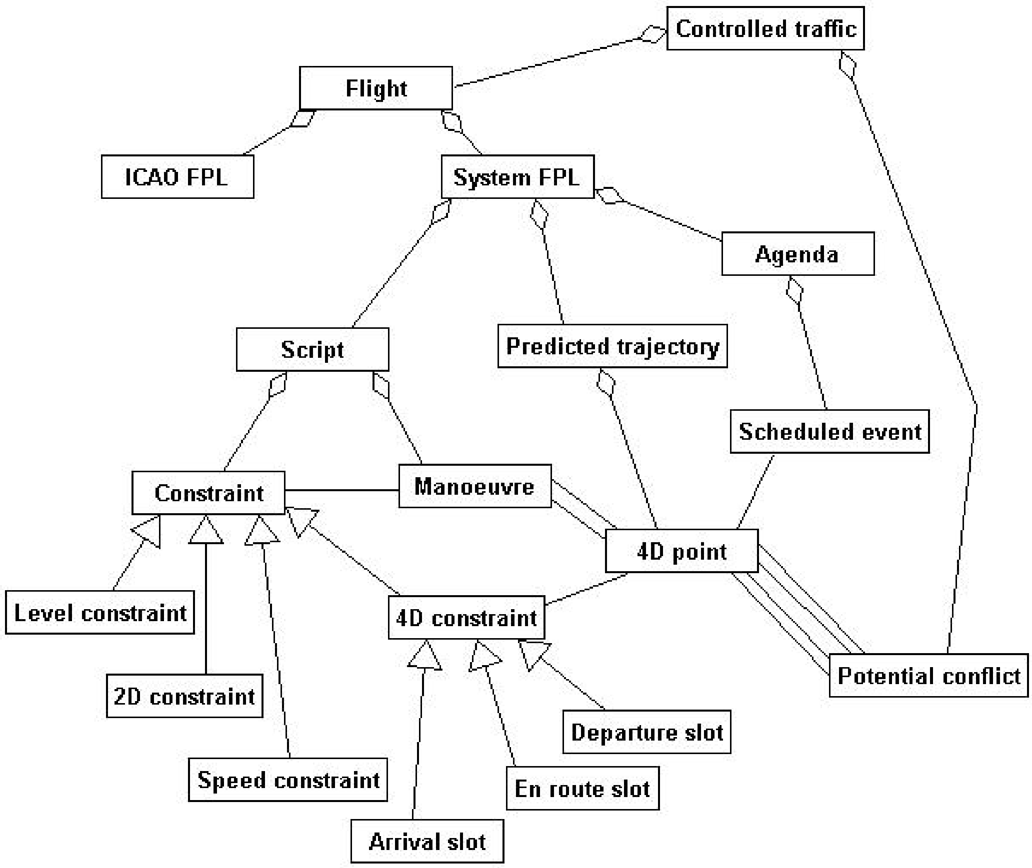


Figure AE.1: Flight data model

The model is derived from the model proposed in the 1997 FDP interoperability study. The table below describes the classes.

Class	Description
Controlled traffic	The container for all flights
Flight	The container for all information related to a flight used for predicting the behaviour of a flight
ICAO FPL	The reference initial flight plan as specified by OACI, and the history of this plan if changes have been made
System FPL	The FDP view of the flight plan, a container for various kind of fine grained information
Script	The description of flight intentions in the form of manœuvres and applicable constraints

Class	Description
Constraint	The generic class for all constraints. Two types of constraints are considered: general (or strategic) constraints that apply to all flight of a given family (IFR rules, same aircraft type, etc). AIP describes airways, standard procedures that are such constraints. Letters of agreement between ATS units are also strategic constraints. For a given flight, strategic constraints are known before taking off or entry in controlled airspace, with various levels of anticipation. Individual (or tactical) constraints that apply to one flight. They stem from: - Control orders issued by ATC - Regulations imposed by ATFM Constraints applied to a flight can be changed before and during the flight. For instance, if a CDR 3 is opened by the militaries, the 2D constraint that forbids to cross the corresponding TSA is removed from the set of applicable constraints. The script and trajectory can be modified accordingly.
Level constraint	A constraint that limits the accessible flight levels or altitude bands
2D constraint	A constraint that limit the 2D route of the flight
Speed constraint	A constraint that limit the speed range
4D constraint	A constraint that imposes the presence of the flight in a space × time interval
Arrival slot	A 4D constraint where the space constraint is the runway
En route slot	A 4D constraint where the space constraint is in en route airspace
Departure slot	A 4D constraint where the space constraint is the runway
Manoeuvre	An elementary evolution of the aircraft that changes its state as defined by the flight dynamics state variables: position, speed, mass, possibly others (angle of attack, bank angle, airframe configuration, throttle position) depending on the class of flight dynamics model used. Manoeuvres range from standard simple manoeuvres like straight level constant speed segments that change only the horizontal position and the mass (due to fuel burn), level constant rate turns, etc. to arbitrary complex manoeuvres that are not, in principle, expected to occur in a regular civil flight. Manoeuvres are derived from the combination of the horizontal flight path, defined by turning points, and the vertical reference profile, defined by a sequence of predefined airframe and throttle settings for successive phases (e.g. constant CAS/Mach climb)
Predicted trajectory	The ordered sequence of 4D points: 3 spatial co-ordinates and the time co-ordinate. In fact other state variables are also predicted, like the speed vector, the current mass and mass derivative (fuel flow). The trajectory is computed from the flight script by simulating the flight of the aircraft, using the appropriate flight dynamics model, the weather forecast data along the flight path, the company operating rules (that are values to be assigned to manoeuvres like the CAS and Mach values for the CAS/Mach climb phase, for the given aircraft type). The flight envelope protection is part of the flight dynamics model and the related constraints are not stored in the constraints of the data model.
4D point	The predicted value at a given future time of the position of a flight. A predicted 4D point can be linked to: The beginning and the end of a manoeuvre The crossing of an airspace volume An action can be attached to a 4D point, than can be triggered when flight path monitoring detects that the flight has reached the point. For instance, traffic load monitoring can update the current occupancy of an airspace volume when one boundary point is reached.
Agenda	The sequence of significant events that will occur during the flight
Scheduled event	Any time-based event that needs to be stored and retrieved when the occurrence time is reached. Scheduled events are most often linked to predicted 4D points by a time translation. For instance, in the OLDI co-ordination protocol, the ACT message sending event is scheduled 10 minutes before the expected boundary crossing, which is a predicted 4D point.
Potential conflict	The set of 4D points that describe one separation loss and subsequent recovery for two flights.

The associations (other than aggregations) are commented below:

Association	Description
Constraint – Manoeuvre	The generic association between a constraint and a manoeuvre. The constraint places a limit on the state variables. The multiplicity of the link is 0 to many. For instance, a speed restriction to 250 kts below FL100 applies to all manoeuvres that compose the flight path from crossing FL100 down to the runway.
Manoeuvre – 4D point	Each manoeuvre starts and ends at identified 4D points that are stored into the trajectory.
Scheduled event – 4D point	Scheduled events are related to one 4D point of the trajectory, at least the take-off 4D point (departure aerodrome and take-off time), which is the time origin of the flight.
Potential conflict – 4D point	Each potential conflict is defined for a pair of flights such that there is a loss of separation time and a separation recovery time, and the respective 4D points of each trajectory are linked to the conflict.

Annex E.2. Connected models

The flight data model is devoted to the prediction of flights' behaviour. Other models address the rest of operational data and are connected with the flight data model through precise classes.

These models are:

- The surveillance model, which associates the observations to the predictions
- The airspace model, which holds the environment data
- The flow and capacity model, which covers airspace resource management aspects

Annex E.2.1. Airspace Model.

The model depicted below shows only a few typical classes for connecting flight data to airspace data. System FPL, Script, Constraint, Predicted trajectory and 4D point are classes already defined in the flight model.

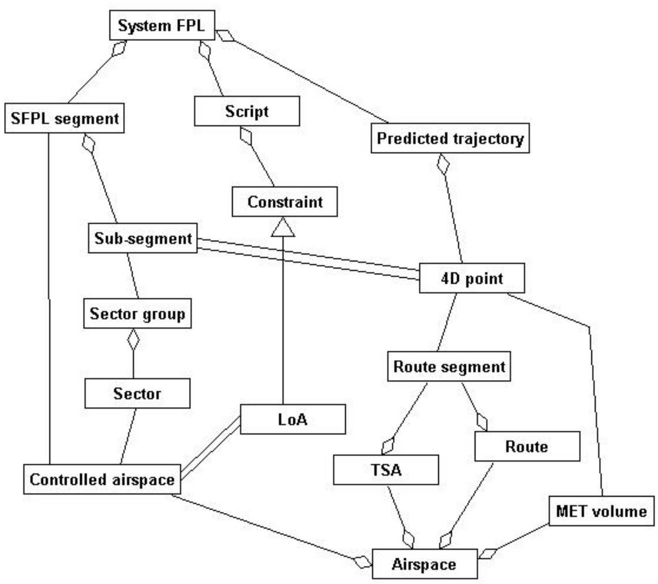


Figure AE2: Airspace model with connections to FD model

Class	Description
SFPL segment	A part of a SFPL that maps to a period of the flight such that it is continuously under the control of a single ATC authority
Sub-segment	A part of a SFPL segment that maps to a period of the flight such that it is continuously under the control of a single control team
Sector group	A set of sectors manned by a single ATC team
Sector	A unit volume (or, by extension, volume plus traffic type and possibly flight phase), for allocating control tasks to teams
Controlled airspace	The part of the airspace that is submitted to ATC. Services depend on ICAO categories that could be merged in the Managed Airspace regime.
LoA	Letter of Agreement between ATS providers
Route segment	A part of a route limited by two significant points: named points on an airway, turning points of the route, entry/exit of a given volume, etc.
TSA	A temporary segregated area
Route	Generic term for Airway, PDR, CDR1, 2 or 3 or tactically assigned direct route
MET volume	The elementary volume used for describing the atmosphere state (both forecast and nowcast if available)
Airspace	The container of all airspace elements

Significant associations are described below.

Association	Description
SFPL segment – Controlled airspace	The generic association between a part of the SFPL (and the corresponding part of the flight) and an ATC authority. In general, associated to the traversal of the AoR of a control centre.
Sub-segment – Sector group	Relates a part of a SFPL segment to a control sector of some other operational task, with a single allowed authority (e.g. ground control on taxiways, on aprons)
Controlled airspace - LoA	The association that allows imposing ATC constraints on transfer conditions between adjacent controlled airspaces. (In the Flight model, constraints are linked of 4D points)
4D point – Sub-segment	The association between a sub-segment and the beginning and end of this sub-segment in the trajectory (4D points). In en-route airspace, the 4D points are also the entry and exit points of the sector group.
4D point – Route segment	The association between the trajectory and the route segment. In the case of TSA, the entry/exit points into/from the TSA or the start/end points of the CDR3 which crosses the TSA

Annex E.2.2. Surveillance model

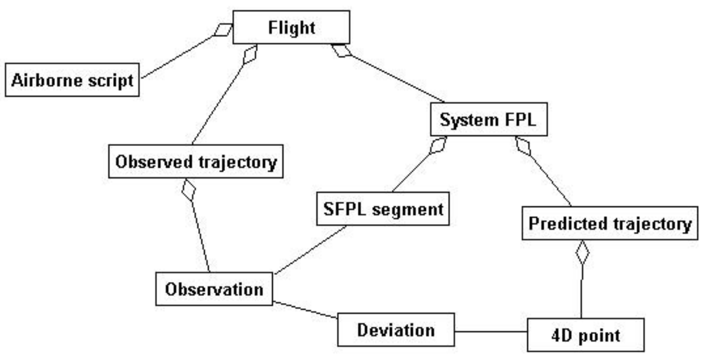


Figure AE.3: Surveillance model and connection to FD model

Class	Description
Observed trajectory	A generic class for the result of tracking, using one or several sensors, independent, co-operative or dependent surveillance tracks fusion
Observation	An individual observation of the flight in the form a state vector. The content of the state vector depends on the surveillance means.
Deviation	The vector difference between a predicted state vector and the observed state vector according to a conventional definition. For instance, the predicted trajectory is he reference, and for a given time, the predicted position is compared with the observed position, using the vertical plane that contains the observed position and is orthogonal to the trajectory.
Airborne script	Flight intentions that are provided by ADS or enhanced Mode S are not considered part of the observation. They are the airborne version of the flight script, and can be made available to the ground.

Significant associations are described below.

Association	Description
Observation – SFPL segment	This association is needed for SSR code management, since the SSR code assignment process is based on ATSUs organisation. In principle, a flight retains the same code in the AoR of a given ACC. ORCAM rules allow to retain the same code for several AoR inside larger regions. In any case, for secondary surveillance, the SSR code is part of the observation.
Observation - Deviation	This association traces a deviation object to the observation
Deviation – 4D point	This association traces a deviation object to the prediction

Annex E.2.3. Flow & Capacity model

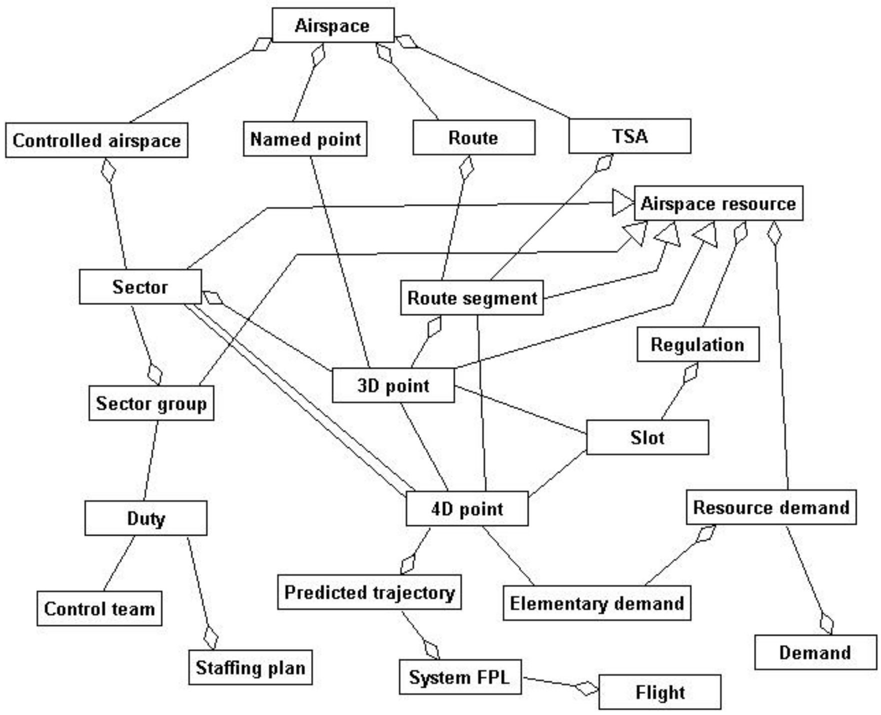


Figure AC4: Flow & capacity model and connection to FD model

The following table describes only the classes that are not defined in previous models.

Class	Description
Named point	A published point that defines 2D co-ordinates without ambiguity
Airspace resource	The generic class that restrict the traffic capacity due to a limited capacity
3D point	A named point with a flight level or an altitude. A special kind of airspace resource, with limited arrival rate. Generally used as the entry point in a compound resource (sector)
Regulation	A set of slots associated to a resource
Slot	A time used as the arrival time of a flight at a given resource. A slot is actually a 4D point.
Elementary demand	The demand associated to a given flight. The time of the demand is the time of a 4D point in the trajectory.
Resource demand	The collection of the elementary demands for a resource
Demand	The container for all resource demands
Duty	The assignment of a control team to a sector group. Applies to both predicted and actual situation
Control team	A set of individuals (2 or 3) assigned to a sector group
Staffing plan	The set of duties, both predicted and actual.

Significant associations (other that aggregations) are described below.

Association	Description
Duty – Sector group	The association that traces duties to sector groups
Duty – Control team	The association that traces duties to control teams
4D point – 3D point	The association which denotes that a flight occupies the 3D point at the time of the 4D point
3D point – Slot	The association that locate the slots at precise co-ordinates in space.
4D point - Slot	The association that relates the predicted presence of the flight at the slot point. This association holds only if the slot is assigned to the flight.
4D point – Elementary demand	This association determines the occupancy of the resource by a flight

It is worth noting that the flow and capacity model is used both at pre-tactical and tactical times.

ANNEX F: FLIGHT DATA CONSISTENCY

Annex F.1. Introduction

Data consistency is a property of several separate data items that model the same real world object.

Formally, Considering one real object X and several models of this object M1, …, Mn, data consistency could be expressed as a n-ary function: C(M1, M2, …, Mn), which returns values either in {true, false}(in this case, C is a predicate), or in another value set, for instance, a discrete set like {low, medium, high}, a number set like the interval [0, 1]. Another name for function or predicte would be “metric”, in the sense of Quality Assurance & Control. In the note, we propose some guidelines to identify which function would be relevant for FD consistency.

For supporting the presentation, we take the simple ATC example: the time estimate for flying over a geographical point for a given flight. The real world object is an “event”, encompassing a flight, a geographical location and a time of occurrence. This is predicted by separate systems, observed by surveillance systems and is stored in many places in he current ATM systems.

Each data item has a data type, and a value. A data type can be structured (like the event example) or elementary.

For instance, different structured data type for the example could be specified as follows in a given system:

<fly-over event 1>::= <flight id> <3D_point> <time>

with:

<flight id>::= *unique id assigned by a central system (e.g. IFPS)*

<3D_point>::= <X co-ordinate> <Y co-ordinate> <altitude>

<X co-ordinate>::= *the X position in a local flat co-ordinate system*

<Y co-ordinate>::= *the Y position in the same local flat co-ordinate system*

<time>::= *an interval in time units (e.g. seconds) from a given time origin*

and, in another system as:

<fly-over event 2>::= <adep> <ades> <EOBT> <callsign> <lat> <long> <FL> <hour> <minute>

The values for a given event could be as follows in each system.

(1234456, (456.32, 872.34, 32000), 3215430514)

(LFBO, LFPG, 1445, AF1234, 453000, 21000, 320, 15, 8)

Annex F.2. The type consistency property

Data are consistent only if their types are consistent. This means that there is a bidirectionnal mapping from one type to the other that permits “data conversion” from one type to the other.

In the example, to have consistent event data types:

- We need a mean to associate the classical “flight key” made of 4 fields: ADEP, ADES, callsign and EOBT used by data type 2 to the unique flight id used by data type 1 in both directions. The central system that allocates unique ids would probably maintain a table of allocated ids with associated flight keys, but rules are needed to handle exceptions, for instance when some of the 4 key fields are not identical with the table entry (partial match).
- We need a mean to convert from/to lat/long co-ordinates to/from the local flat co-ordinates. Accuracy issues may occur when moving far from the tangency point of the projection plan and when the least significant digit does not refer to the same order of magnitude in distance measure.

- We need a mean to convert from/to the hour/minutes daily time to/from the local time co-ordinate. Accuracy issues may also occur here.

Annex F.3. The value consistency property

The value of a structured data item is composed of the values all its elementary data items. If the type consistency property is satisfied, we can consider elementary value consistency only.

Elementary values are either discrete or continuous.

Discrete values are taken from a base set. For instance, LFBO is a value taken from the ICAO 4 character airport identifiers list. Z23P is not a valid airport identifier. Two discrete values of the same type are either equal or different. So discrete data items are consistent if, after conversion to the same type, they have the same value.

Continuous values are real numbers. They are characterised by figures of merit (FoM) that indicate where the real value is likely to reside inside an interval (see section 0). After conversion, continuous values are consistent if they have overlapping intervals. The overlapping of intervals shall relate to the figures of merit according to a consistency criterion.

For instance, an accuracy FoM could be denoted X (#z,%y), x and y being positive numbers, # and % each denoting one of "+" or "-", such that X#z ≤ X%y, which means that the value X is expected to be somewhere between X#z and X%y. This is a classical tolerance annotation. Let us suppose that systems 1, 2, 3, … give values for X: X1, X2, X3, … with different FoMs: (-Z1,+Y1), (-Z2,+Y2), (-Z3,+Y3), …such that Y1 ≥ Y2 ≥ Y3≥…, Z1 ≥ Z2 ≥ Z3≥…,

A "strict" consistency criterion would be satisfied if the intervals are nested, the larger one including the smaller one, in other words, bounds are such that X1-Z1 ≤ X2-Z2 ≤ X3-Z3 ≤ … and X1+Y1 ≥ X2+Y2 ≥ X3+Y3 ≥…

A weaker consistency criterion would be that the intersection of all intervals is non-empty: if k is such that Xk+Yk ≤ Xi+Yi, for all i ≠ k, and if m is such that Xm-Zm ≥ Xi-Zi, for all i ≠ m, then Xk+Yk ≥ Xm-Zm. In other words, all intervals have at least one value (point) in common.

Annex F.4. The time consistency property

Since there are separate data items for representing the same real object, it is possible that when the real object changes, the data items are updated at different times, for various reasons, but at least because of update propagation inside a computer (if all data items are managed by a single processing node and the change is captured by one single "sensor").

For N data items, that model the same real object, the time consistency is expressed as the time interval between the update of the first data item and the update of the last data item.

At one end, if data items are simply one local persistent data stored on a disk and the same mirrored data on another disk, the time consistency is high, as measured by the time to perform two concurrent write operations on disks. A few milliseconds.

At the other end, if data are initial flight plans delivered by IFPS, to several ATSUs, time consistency between copies of the flight plan, as processed and stored by local FDP systems, is very low. By design, systems will choose different times to expand the plan, and the inconsistency will end only when the last ATSU has expanded the FPL to create its own system flight plan.

Annex F.5. About uncertainty

Uncertainty is not to be confused with consistency. Uncertainty is an intrinsic attribute of a real-object, most often a measure or a prediction, and as such, uncertainty is a structured or elementary data type, with a value. When the same real object featuring an "uncertainty" attribute is represented by separate data items, the consistency criteria described above apply to the data items.

Example. In the ATM system, there are several time horizons for predicting flight behaviour. Coming back to the fly-over event, the time is one elementary data item, belonging to both models introduced in 0. It is predicted in the ATFM FM, in the ATC FM and in the FMS. The time horizon is segmented according to several significant events:

- The ATFM slot allocation.
- The DMAN take-off slot allocation
- The take-off.
- The observation of the actual fly-over event

Let us first consider the ATC FM. The uncertainty of the predicted time over a point of the route of flight is depicted below as a function of the time (uncertainty scale is indicative). The time horizon increases from right to left.

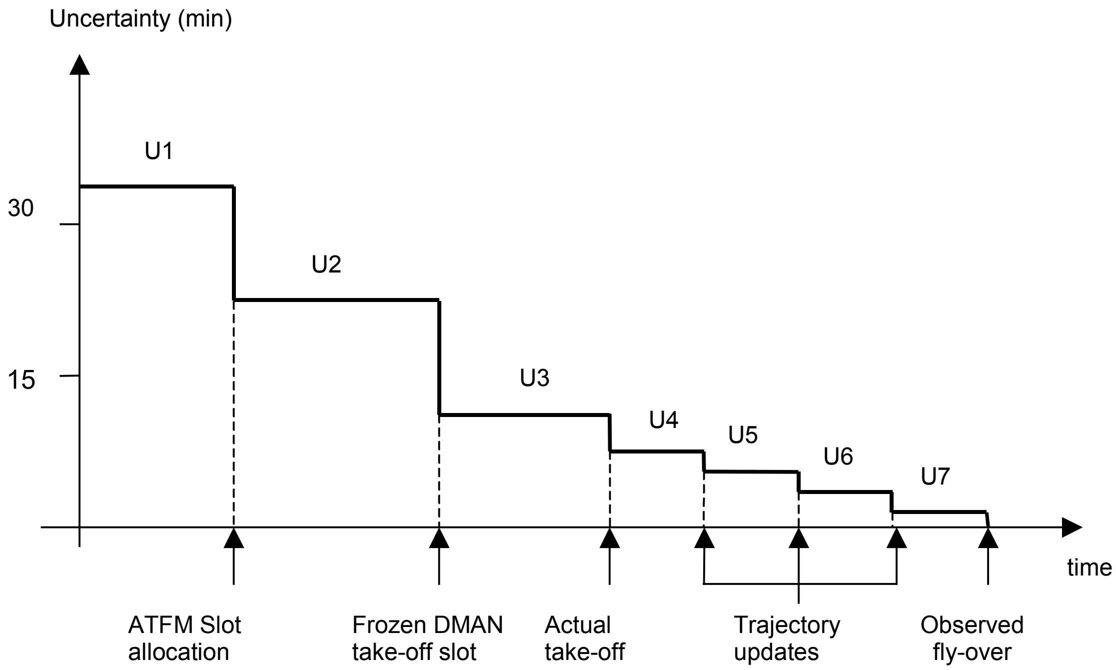


Figure AF.1: Uncertainty of an estimated time over a given point for a given flight as function of time.

The evolution of the uncertainty on the time over the route point when considering the onboard FMS, has the same overall shape. The difference with ATC, is that the FMS provides a better accuracy of the prediction after take-off, provided that weather data and ATC constraints along the path are all known by the FMS.

What is important to notice is that the source of uncertainty is not the same in each time segment. Until take-off, most of the uncertainty stems from the take-off time. After take-off, the time origin of the predicted 4D trajectory is fixed. The remaining uncertainty is due to the performance of the TP, the update rate by flight path monitoring and the accuracy of input data, including the weather. In more details, assuming a busy airport and a peak period:

- Before allocating the slot, there is no actual knowledge of the probable take-off time. Delay history for the same flight for the same day of the week, might indicate the average delay imposed by ATFM, and uncertainty on the take-off time could be for instance 2 times the standard deviation on both sides of the mean value of the take-off time distribution.
- When the slot is allocated, in principle, the take-off time shall be in the time window: CTOT-5min, CTOT+10min. However, departure slots are often not respected at large airports. Assuming a strict

adherence to the slot, the uncertainty on the take-off time becomes the 15 minutes interval around the CTOT.

- If the airport is equipped with a DMAN that controls the take-off sequence, a take-off slot is assigned to the flight, inside the ATFM slot window, with a reduced time window, owing to competing runway users in the sequence. Thus, the uncertainty on take-off time is reduced again.
- When take-off takes place, the uncertainty on take-off time is zeroed and the remaining uncertainty is generated by the performance of the TP, including the feed-back from surveillance and the accuracy of both flight intention data end environment data. The drift rate of modern ground-based TP is about 7% in longitudinal position. This means that when it is predicted at time T0 that the longitudinal position will be U at time T1, the flight is observed at position U at an actual time Tu such that T1 – 0.07(T1-T0) < Tu < T1 + 0.07(T1-T0).
- As long as the aircraft is airborne, Flight Path Monitoring (or conformance monitoring), compares the predicted 4D trajectory and the observed position. When a predefined tolerance threshold is crossed, the 4D trajectory is updated taking the observed point as the new origin of the prediction.

To investigate further the causes of trajectory uncertainty, let us present in the form of a cause/effect diagram, the computation of a 4D trajectory.

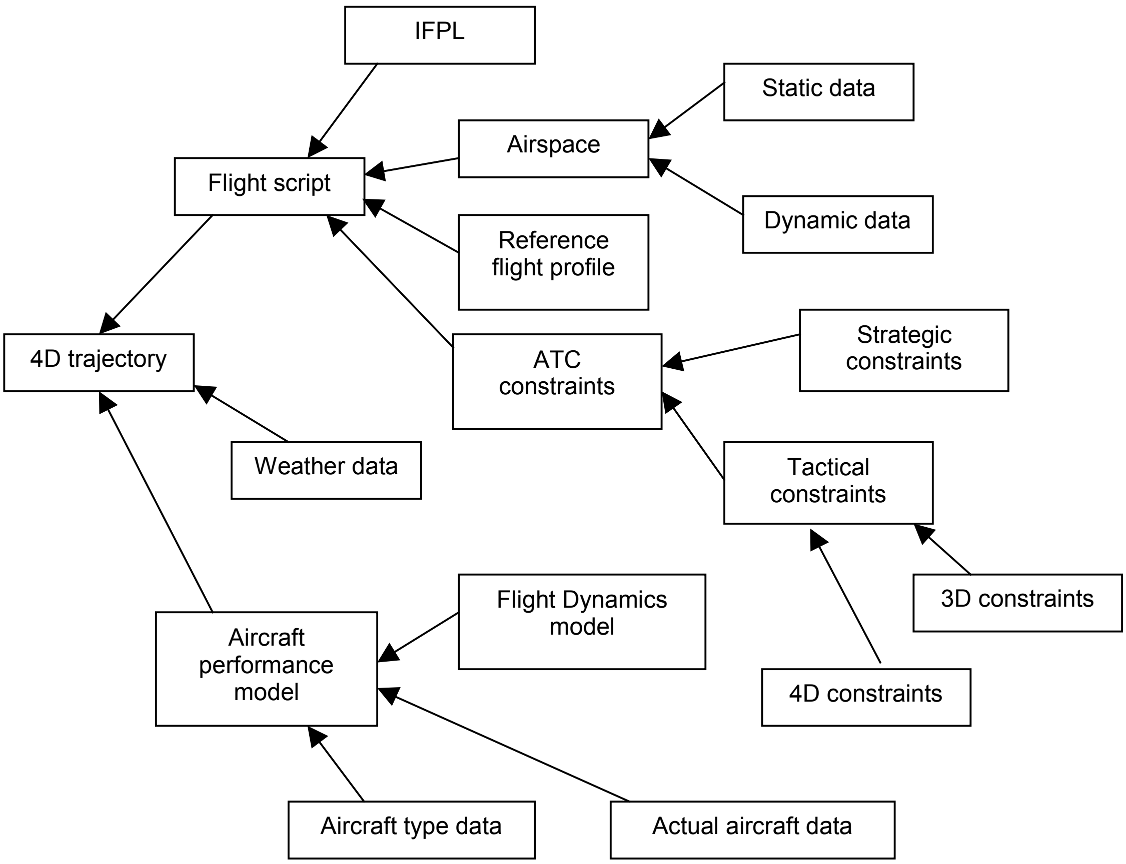


Figure AF.2: Cause/effect diagram linking algorithms and input data to the 4D trajectory.

The flight script represents the detailed “flight intentions”. In short, it includes the 2D navigation plan, expanded from the IFPL route, the flight profile in terms of expected phases: at least climb to RFL, cruise between TOC and TOD, and descent to the IAF. ATC constraints introduce sub-phases of the flight that are either known from the beginning (strategic constraints like restricted flight levels), or added during the flight (tactical constraints like departure slots, conflict avoidance manoeuvres, direct route segments, etc.).

The aircraft performance model is composed of a flight dynamics model that allows the simulation of the flight. There is a wide range of potential models, from the differential equations of motions with all control laws and actuator effects to tables based on recorded flights parameters.

The table below presents a short survey of the causes of uncertainty on a single data item, and of the cause of inconsistency between separate data items that represent the same real object.

For instance, in the case of the IFPL:

- On the one hand, there is “practically” no uncertainty on one single IFPL representation, provided that it is syntactically and semantically valid. This is due to the fact that the FPL is already a abstract object, specified by ICAO rules. Thus, firstly, the syntax is formally checkable. Secondly, the semantics of the FPL fields can be checked against reference data: e.g. airways and named points exist in the published airspace data, the aircraft type is known, etc. However, there is indeed some room for interpretation after validating the individual values of fields. For instance, the route might be underspecified in the FPL (several routings are possible between two points, and DCT is not mentioned), or a CDR1 is scheduled to be closed at the day/time of flight, etc. This is not an uncertainty on the FPL itself.
- On he other hand, inconsistencies may occur between systems that hold copies of the IFPL. By design, there are two separate domains: the FMS and the ground systems. In short, on the one hand, the AOC system provides the pilot with the paper flight plan to be entered in the FMS (or the AOC system downloads the flight plan into the FMS). On the other hand, the AOC system files the flight plan by sending a message to the IFPS. The IFPS processes the FPL to determine interested ATSUs, and forwards the FPL to them, in the form of an IFPL. Each ATSU processes the IFPL to update its current flight database with the internal form of the IFPL. Some of them use manual input of FPL (as in UK). Consequently, there are several potential sources of inconsistencies.

Item	*Description*	*Cause of uncertainty of a single data item*	*Cause of inconsistency between data items*
IFPL	The initial flight plan as distributed by IFPS and as input into the FMS	None, if all fields are syntactically and semantically valid	Multiple input into FMS, IFPS and ATSUs Communication failure between IFPS and some ATSU
Airspace/static data	The description of airspace, including procedures	Approximate description of procedures.	Multiple input into separate AIM systems
Airspace/dynamic	The state change for dynamic airspace items (CDR/TSA, QFU)	None	Separate notification to systems from authority. Manual operational supervision commands
Reference flight profile	The sequence of vertical phases and subphases that correspond to flight contral laws	None	Different reference profiles between FMS and ATC, and between ATC units
ATC constraints/ strategic	Constraints that apply to all flight in a given situation (e.g; LoA for dedicated transfer levels between ATSUs on a given route)	None	LoA are generally not published, thus not known from FMS navigation databases. Moreover, LoA are mostly bilateral agreement and are not known from ATFM.
ATC constraints/ tactical/3D or 4D	Constraints that apply to a specific flight (e.g. departure slot (4D), assigned SID (3D), tactical manoeuvre for conflict avoidance, etc.)	Uncertainty depends on the constraint. Time uncertainty on departure slot. Open tactical orders (take heading), conditional tactical orders, etc…	Most tactical orders are not input into a system nor disseminated to other FD users. Thus the actual short term navigation plan is inconsistent among separate systems.
Weather data	Atmosphere data: temperature, QNH, winds aloft, icing conditions, adverse weather areas, etc. Actual data and forecast data	Uncertainty is due to the prediction horizon, the refreshment rate, the averaging of values over airspace volumes, etc.	Each system is served by a dedicated meteo server. The airspace mesh for predictions varies from very coarse to coarse. Airport data are provided to pilots and some systems (e.g. QNH to RDPS for MSAW).
Flight dynamics model	The type model used for simulating the execution of a flight. The Eurocontrol taxonomy has 4 levels: A to D, with A denoting FMS and detailed flight simulators, B denoting point-mass approximation, C denoting parametric model of flight phases, and D tabulated performance per aircraft types. Most operational systems use D models.	Uncertainty is due to the precision of the model. D models are calibrated with radar tracks and use average observed performances as input. The uncertainty is thus related to the dispersion of the observed parameters. It could be represented by the range of observation, or by the coefficient of variation or another statistical index.	Each ground system has its own flight dynamics model, with its own required input data. The FMS has the most accurate model for the aircraft.
Aircraft type data	The data that are needed in the flight dynamic model to simulate the flight an aircraft of a given type. Types range form a few types (piston engine, turbo, 2 jets, 3 jets, 4 jets, military, Concorde) to a list that matches actual aircraft types (airframe and engine settings)	There are more real types than model types, therefore, equivalence rules are used to assimilate derived types to a base type. For instance, there could be three A330 types according to GE, PW or RR engines, or one A330 type, regardless of engines, with average thrust and fuel consumption parameters. When new airframes are made operational, new types can be created or declared equivalent to existing types.	Each ground system has its own set of aircraft types performance database, compliant with the flight dynamics model. The FMS has a very accurate model of the flight dynamics parameters.

Item	*Description*	*Cause of uncertainty of a single data item*	*Cause of inconsistency between data items*
Actual aircraft data	The data that refine the aircraft type data, for instance the actual take-off mass, or the actual parameters of a given control law (e.g. Constant Mach climb at M0.7)	Uncertainty is due to the fact that actual data are generally unknown	Same as before. Some ground systems could be informed of some actual data. The FMS has all actual data at hand by design.

Annex F.6. Behavioural consistency

Annex F.6.1. Introduction

The behavioural consistency in the present context, is a property of separate behavioural models that represent the same real world process. Therefore the models are abstract process descriptions with respect to the real process. The real process as well as the model processes are “observed” through “events”. The real process is unknown (it is a black box), whereas the model processes are “glass” boxes for their designers and black boxes for others.

Informally, processes will be “consistent” if external observers see the same events and the same ordering of events from each process. Another name for this property is “observation equivalence”, being aware that this is a fairly connoted word in process modelling.

A “strong consistency” criterion would require that all processes generate exactly the same sequence of events. If one process generates an event, all other processes generate this event also.

A “weak consistency” criterium requires only that the common events among processes are in the same order. Common events are generated by at least two processes.

Example: The execution of a flight is a physical process, that is modelled in different ways by the ATM systems, among others: the on board FMS, the ATC FM, the ATFM FM. This is depicted below. A small part of a route, with points A, B and C crosses an airspace volume R, considered as a resource by ATFM. A flight cruises along this route.

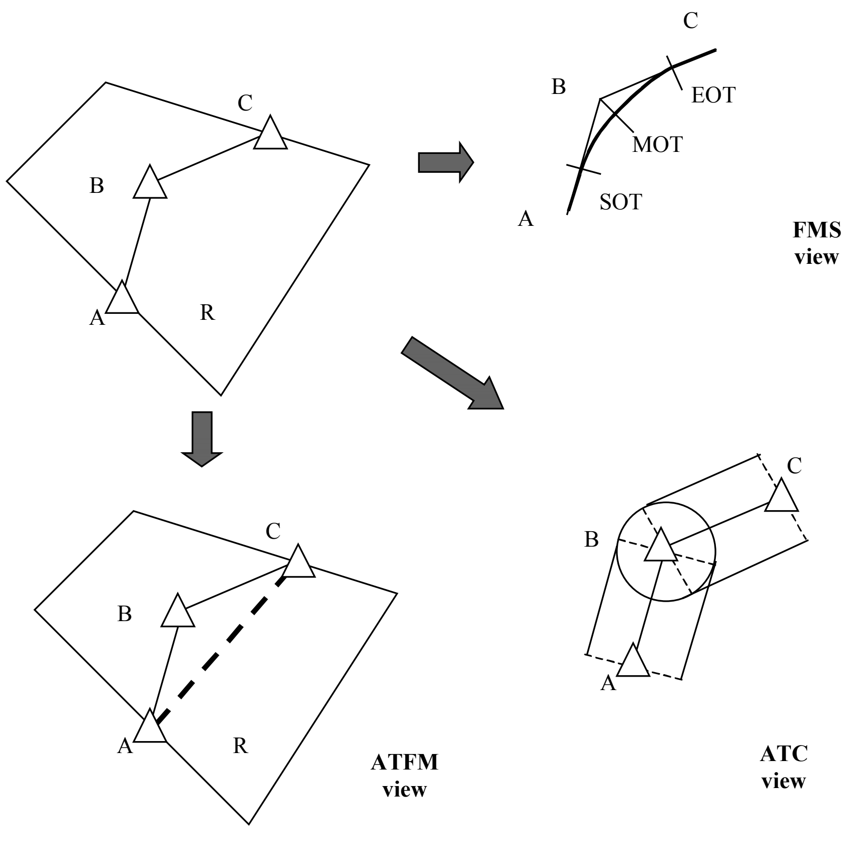


Figure AF.3: Various predicted views of a flight.

The real execution of the flight is unknown. When executed, the real process, is observed by the surveillance system, in the form of the radar track. Significant events are all the individual positions reported by the tracking function.

When predicted, there are at least two models:

- The finest model is the trajectory generated by the FMS. If it is not explicitly required to fly over the B point, the FMS optimises the trajectory to make a so-called "normal turn", passing "abeam" B. The significant events for the FMS, are the start of turn (SOT), the middle of turn (MOT) and the end of turn (EOT), where the aircraft control laws are changed.
- The coarser model is the model used by ATC and possibly ATFM. Depending on the class of the flight dynamics model used by the TP, the turn manoeuvre can be represented as a FMS-like turn (with estimated standard bank angle), or simply ignored and replaced by an instantaneous heading change at the turning point (Current ATC systems ignore turns: when needed they are approximated by a sequence of short straight segments).

The difference between ATC and ATFM stems from the further usage of the output. On the one hand, ATC is interested in the estimated trajectory for tactical planning, conflict detection and conformance monitoring. The trajectory itself is the relevant output for ATC. On the other hand, ATFM is interested in the control workload of airspace resources. The flight entry and exit times relative to resource R are the relevant output for ATFM. A direct flight from A to C with the same traversal time, would give the same result for ATFM. Trajectories are an intermediate product for resource occupancy evaluation. Moreover, in the pre-tactical phase, some ATFM tools do not compute any trajectory, but simply retrieve entry/exit times at resource boundaries from flight data archives of a reference traffic day to determine the base workload. Thus in Figure , the dashed line symbolically represents the occupancy of the resource as would result from retrieving the entry and exit times. The ABC routing is used for tactical computation (for instance, slot allocation). It could be provided by ATC to ATFM, neglecting the geographical scope limitation of ATC.

The processes that are predicted by the FMS, ATC and ATFM are modelled by hybrid finite state automata, as depicted by Figure AD4. In each automaton (discrete) state, the process changes the continuous state of the flight in a specific way, which does not matter in the present discussion. The only assumption made is that the continuous behaviour in a given discrete state is described by a continuous model and satisfies a set of constraints, called an invariant. The transition to another discrete state occurs either when an internal state event occurs that violates the invariant, or when an external discrete event is notified. Upon transition, the continuous state model and the invariant can change.

For instance, let us consider the FMS model. We assume that the FMS implement a single model of the flight dynamics of the aircraft, with a complete rendering of control laws, mass, inertia, aerodynamic coefficients, and so on.

- In the first state, the equations of motion are integrated for simulating the first segment (from A to SOT). The invariant expresses that the speed, heading and level are constant, and that the distance (or time) to the Start of Turn (SOT) is greater that 0. The FMS adjusts the control law that satisfies the invariant.
- The transition labelled SOT is fired when the SOT is reached. The FMS automaton moves to the second state. It is a state event, since it results from a continuous evolution of one state variable.
- In the second state, the control law is changed to progressively reach the target bank angle and execute a stabilised half turn. The invariant is changed accordingly, for instance, the bank angle has to stay below a limit, the speed is constant (which means that thrust is raised a bit), the heading is between the heading at SOT and the expected heading when crossing the bisector of the (BC, BA) angle, etc.
- Etc.

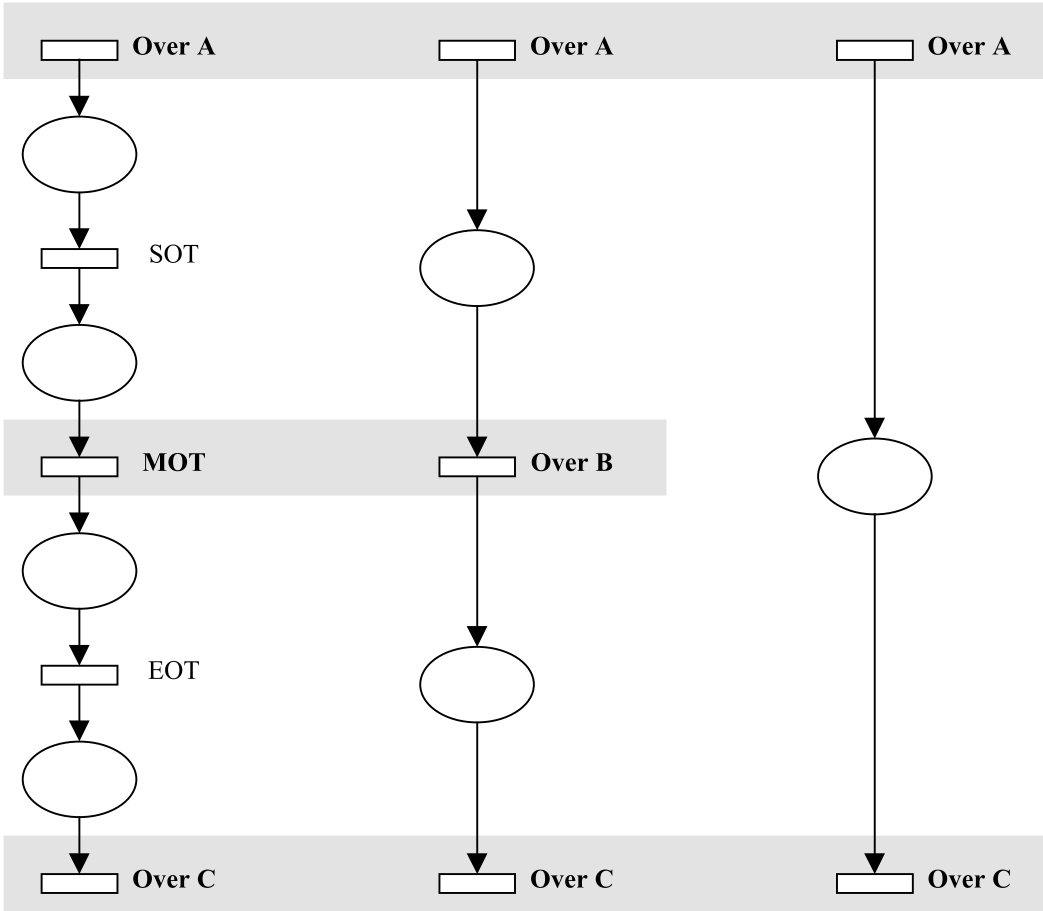


Figure AD4: Various flight models: FMS, ATC or tactical ATFM, pre-tactical ATFM.

The behavioural consistency is ensured if observed “matching events” occur in the same order. Matching events are events that represent the same real event and are consistent according to a consistency criterion (as indicated in the data consistency section). Therefore, events’ occurrence times shall have consistent values, for instance, overlapping uncertainty intervals for predicted events.

Matching events for the 3 flight models are collected in grey boxes in Figure .

However, in the ATM system, observation is based on various technical means. For instance, flying over a point is an event that can be observed in the following ways:

- It is observed by the pilot owing to its own navigation instruments;
- Where radar coverage exists, it is independently observed by ATC owing to the radar tracking and flight path monitoring (FPM) functions;
- Where radar coverage does not exist it is notified to ATC by the pilot through voice report or by the FMS through ADS report.

In the case of dependent surveillance, the FMS and ATC events match by design, since the ATC event results from the FMS event (time consistency might be an issue, due to significant latency in satellite-based communications).

In the independent surveillance case, they do not match automatically.

To illustrate the problem, let us consider the case of flying “over B” as predicted by ATC. The FPM algorithm will declare that the flight has flown over B, if the last reported radar position for the flight:

- Is inside the lateral band centred on the A>B>C route,

- Is in the downstream half plane determined by the bisector of the (BC, BA) angle; whereas the previous reported position was in the other half plane.

For the FMS, flying over B does not occur at all. The flight passes abeam B, at a distance that depends on the turn radius.

In that case, the matching rule relative to a given turning point, is that a fly-abeam event generated by a FMS directing the execution of a normal turn is equivalent to a fly-over event generated by the ATC system, provided that the flight path remains in the lateral tolerance expected by the ATC FPM function.

Annex F.6.2. Application to FD consistency

Up to now, when discussing the FD consistency problem, the focus has been put on data modelling, especially advocating the definition of a common reference data model. More recently, the focus has moved to service provision, in a sense that still needs to be clarified. In this vein, it would be recommended that distinct systems provide standard APIs to users (connected systems including HMIs), for retrieving information and requesting services. Unfortunately, the FD consistency problem cannot be solved uniquely through data harmonisation and API definition.

The FD consistency problem incorporates a dynamical dimension that is overlooked up to now. Data life cycles reflect real processes, whereby data are updated when operational events occur. In the current models, as implemented by ATC and ATFM systems, the processes are reified in the form of “plans” (system flight plan, navigation plans, reference profiles), that are very different among systems, and do not exhibit matching events in the sense given above. Only loose synchronisation is performed for a very few events, for instance, updated flight plans are transmitted with most operational messages between ATS units. Downlink of aircraft data will certainly improve the consistency of plans between heterogeneous systems. In fact, coming back to Figure , this is somewhat as if the FMS provided the ATC with its predicted sequence of observable events. This implies that the FMS events are correctly interpreted by the other systems. Typically, FMS auxiliary navigation points like SOT and EOT are not useful for current ATC systems, and MOT is not directly related to point B. The situation could change if the ATC model become closer to the FMS model. This is what is advocated when proposing an ATC flight script in the form of manoeuvres, similar to FMS flight segment. Another solution, investigated in projects like AFAS, consists in replacing the ATC model by the FMS model, provided by the FMS to the ground control whenever required.

Assuming that a unique source for the predicted flight data is unlikely to be established in the short or medium term, separate systems will continue to predict flight behaviours, using their own model. Consequently, the dynamical models of flights (and environment items when appropriate) implemented by separate systems, should be harmonised in a way that leaves degrees of freedom for implementing detailed algorithms, but guarantees that behavioural consistency is maintained between systems. This means that:

- A reference behaviour of a flight (or a sequence of flights sharing the same aircraft and/or crew, so as to incorporate the AOC and airport operations) shall be carefully defined,
- Various simplified behaviours shall be defined by adaptation to operational requirements of various stakeholders.
- In any case, all the behaviours are kept consistent in a sense that ensures safety and efficiency of operations.

Annex F.7. Conclusion

The present annex addresses several aspects of the “Flight Data consistency” problem. After a review of several data consistency sub-cases, another form of consistency between systems is presented; called behavioural consistency. Behavioural consistency overlap with data consistency since the flight behaviour is modelled by the trajectory that is predicted, stored, distributed just like other data. However, behavioural consistency cannot be solved by simple harmonisation of data types or values, and a set of consistent flight behaviour models tailored for different operational needs shall be specified as a part of the effort to solve the FD consistency issue.

ANNEX G: STANDARDISATION AND CERTIFICATION DEFINITION AND RELATIONSHIP

ANNEX G.1 General principles and terminology

In this section, standardisation and certification are treated simultaneously, as the reason for producing formal standards is to demonstrate the compliance of products and services with the standards, through qualification tests and eventually a certification process.

Also, the production of the technical content is one thing, and the formal publication and enforcement of a standard is another. A regulatory authority has to promulgate the standard and set binding rules for its application.

Once a standard is in place, products and/or services designed, produced and operated in accordance with that standard have to be tested for compliance and ultimately undergo an independent certification; this serves as formal evidence in support of either a safety review or the granting a licence.

The terminology used in this document when dealing with certification related issues relies heavily on ISO and related EN standards as, being internationally recognised and used, they may apply equally to all products and services.

- ***Standardisation***[76] [is the] activity of establishing, with regard to actual or potential problems, provisions for common and repeated use, aimed at the achievement of the optimum degree of order in a given context. In particular, the activity consists of the process of formulating, issuing and implementing standards. Important benefits of standardisation are improvement of the suitability of products, processes ad services for their intended purposes, prevention of barriers to trade and facilitation of technological co-operation;
- ***Qualification***[77] is a process of demonstrating whether an entity [process, product, and organisation] is capable of fulfilling specified requirements. It is the process by which entities needing certification attempt to demonstrate compliance with minimum requirements. It can include desktop exercises or methods of proof of performance by observation (e.g., of a test of system operation) allowing demonstration that the product/operations/person/organisation is established as correct with reference to a standard, specification or drawing;
- ***Accreditation***[78] is the procedure by which an authoritative body gives formal recognition that a body or person is competent to carry out specific tasks. The *accrediting criteria* consist off a set of requirements that is used by an accreditation body, fulfilment to be confirmed by a conformity assessment body in order to be accredited;
- ***Certification***[79] is a procedure by which a third party gives written assurance that a product [product is the result of activities or processes], process or services conforms to specified requirements. It could include as well, but need not be restricted to, the recognition of compliance with requirements or normative documents [standards, technical specifications, codes of practices] that are formally enforced by the regulation; the certification process may call for and make use of various other standards and tools, such as methodologies and/or qualification means, outside any regulatory framework. Certification would not only deal with safety but also all other requirements that would be identified as essential for standardisation, for reasons such as efficiency, or economics. The certification process contributes to the promotion of the standards and ***codes of practices***, as well as to the ***validation*** of their proper implementation;
- ***Certification and accreditation*** therefore comprise the activity of checking the ***product, service***, organisation or person, and the ***verification*** as well as recognition of ***conformity*** with minimum applicable requirements/accreditation criteria, through the issuance of a ***certificate, licence, approval*** or other document as required by applicable law and/or certification/accreditation process. The certification decision can have a variety of different implications depending, among other things, upon the context.

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[76] Ref ISO CEI 2 Guide/EN 45020
[77] Ref ISO 8402
[78] Ref ISO CEI 2 Guide/EN 45020
[79] Ref ISO CEI 2 Guide/EN 45020

- *A* ***regulation***[80] is a document that imposes binding rules or standards, and that is issued by an authorised governmental body.

Based on the ISO definitions, the following terms are used in the document:

1. Certification:

“ Certification ” when applied to **equipment, systems and aircraft**

“ Approval ” when applied to **operations and services**

2. Accreditation:

“ Accreditation ” when applied to organisations and **bodies**

“ Licensing ” when applied to **persons**

ANNEX G.2 Representation of the main functions and their relationship

Annex G.2.1 Overview of the four main functions

Our approach consisted in identifying the generic actors of the certification processes: the regulatory authorities and the accredited bodies conducting certification, the users, the manufacturers and the service providers. These actors are the same in all the fields of application.

Then we identified, through existing definitions and processes, four generic functional roles and their relationship: regulation, standardisation, qualification and certification.

To describe their relationship we resorted to a diagram-based technique of functional decomposition that allowed us to clarify the boundaries and interactions between the functional roles.

"Regulation" is to be understood with a narrow technical scope in this section, covering the promulgation of standards, and their certification-oriented enforcement. It does not encompass other regulatory activities such as market regulations (e.g. the regulation of mergers and monopolies) or procurement directives and although regulatory activities are supposed to take place within a certain legal framework, this section does not discusses the institutional source of authority behind the issuance of regulations. Also, the concrete means that have to be made available to the regulatory authority to admonish and/or punish non-compliant users, manufacturers etc. are not discussed here.

General information on the institutional and regulatory framework is provided at chapter 5. A possible mechanism for allowing the European Commission to undertake the development of binding standards is presented in the last section of this chapter.

In a certification process, the lifecycle of products and services is constrained by two activities, "standardisation" that is located upstream and "qualification" which is located downstream.

"Standardisation" establishes provisions for a common and repeated use, aimed at the achievement of the optimum degree of order in a given context. It is a key technical activity in which manufacturers, providers and users convene and create a community-wide consensus. An important point in respect of the certification process is that a mature standard has to be formally adopted and promulgated by a regulatory authority to come into force. This is a key difference between voluntary “de facto” standardisation as it is widely practised in various industries, and formal standardisation in a regulatory certification context. Obviously, since equipment manufacturers are directly involved in the standardisation process, they can develop their products so as to match future standards, but these products become certifiable only when these standards have been formally adopted as a binding rule by the relevant authority.

"Qualification" is the demonstration of compliance of deliverable products and services to certain requirements (generally expressed in terms of performance, interoperability and safety

[80] Differ from ISO CEI 2 guide, that states “ ***A regulation is a document providing binding legislative rules, that is adopted by an authority*** ”

standards). Acceptable qualification means are defined by the regulation function. Qualification is conducted by the manufacturers themselves (and by the integrators whenever the equipment to be certified is embedded in a wider system). The qualification of user equipment in operational conditions is conducted by the users in co-ordination with the manufacturers and/or service providers.

When several entities co-operate to conduct a qualification, the "regulation" function may define specific responsibilities in respect of the qualification process for each of them.

'Certification" is the approval of the qualification process by some external third parties who make a judgement of value on the means of qualification which are presented to them. It is either conducted by the certification authorities themselves, or, more frequently, by duly accredited bodies (i.e. corporate entities that have been themselves previously submitted to some kind of qualification and certification, so as to make sure that they have the capacity to analyse and assess a qualification dossier). This means that the "regulation" function must also promulgate and control the conditions of accreditation (which could be seen as a special set of standards).

The relationship between "certification" and "qualification" is similar to the relationship between "regulation" and "standardisation" in the sense that a qualified product has the same unofficial status as a mature standard: A correctly qualified product is transformed into a certified product only through the endorsement of its qualification by an authorised certification body. Another similarity is that the certifying entity generally does not conduct the detailed validation any more than the regulating entity defines the minutiae of the technical standard it adopts.

In our context of FDP systems and services, the certification process is indeed two-folded: there is an FDP User Operation-related certification process, and there is an FDP System Production qualification process that must be articulated with the user side at the level of the services made made available at the user/provider interface.

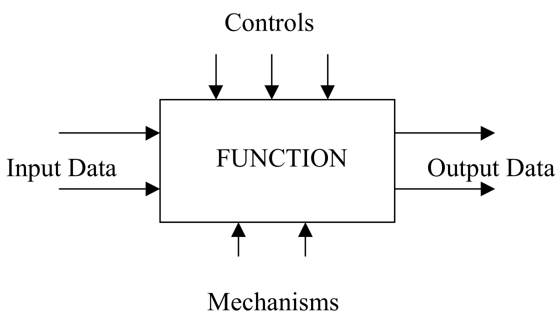
Therefore, the high-level analysis of the certification process enables us to identify four functional roles:

- to standardise,
- to regulate,
- to qualify, and
- to certify.

Using SADT formalisation, each function can be represented as a small diagram (the definition of the four functions have been given above).

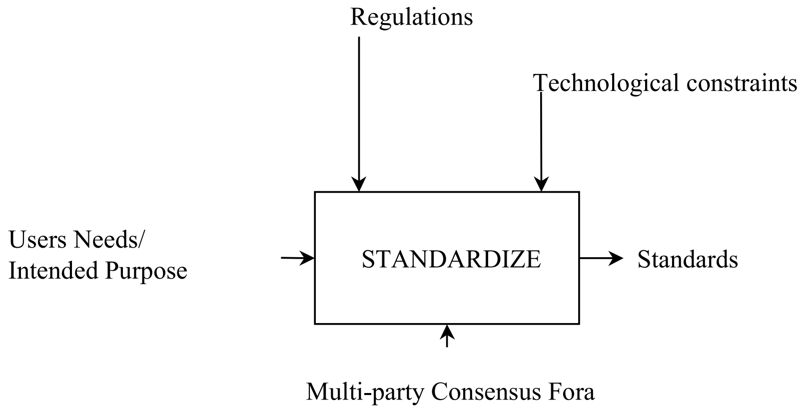
The SADT methodology is a functional analysis tool enabling to describe or to design a process in a system, whatever the intricacy of the system. It is based upon the use of actigram and datagram boxes, which describe the sub-elements of the system.

An actigram box represents a function. The input data (left) are transformed into output data (right) by the function represented in the box. The controls (top) are input that also act on the way the transformation of other input is done and the mechanisms (bottom) indicate the processes by which the function is completed and who is performing the function:



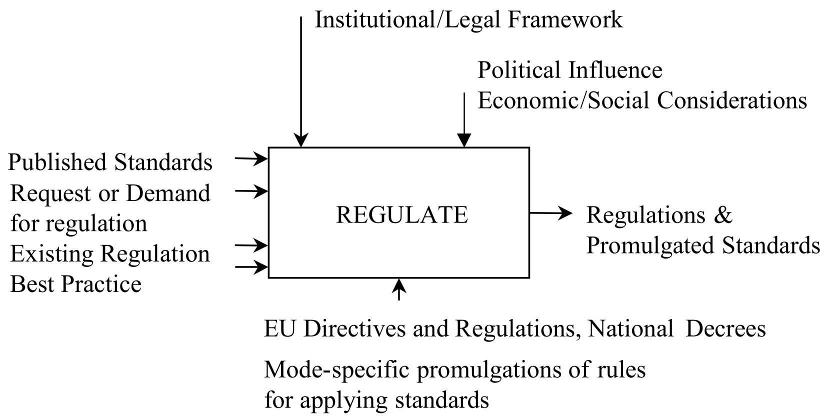
The linking of the different functions that have been identified in a system enables to perform an analysis of the processes and to understand the system. The first step consists in describing the functions at a suitable level and the second step set up the links between them in order to build up functional diagrams. Each functional diagram is analysed and detailed until the understanding of the system is reached.

Annex G.2.2 Standardisation function



The standardisation function starts from the user needs and intended purpose of the product/service under standardisation. The development of standards is generally perfomed by a multi-party forum that converges on a consensus. It uses means and methods such as simulation, models or experiments to complete and validate standards. The control parameters that act on the standardisation process are the regulations (that provide a legal framework), the technological constraints that include current or existing standards, the best practice (i.e. the current know-how), the request or demand for standards development, the operational experience and the economic context (e.g. standardisation used to provide minimum requirement).

Annex G.2.3 The regulation function



The regulation function receives as input the request or demand for regulation, existing regulations and best practice related to the function, and published standards.

The mechanisms by which the function is performed are mainly:

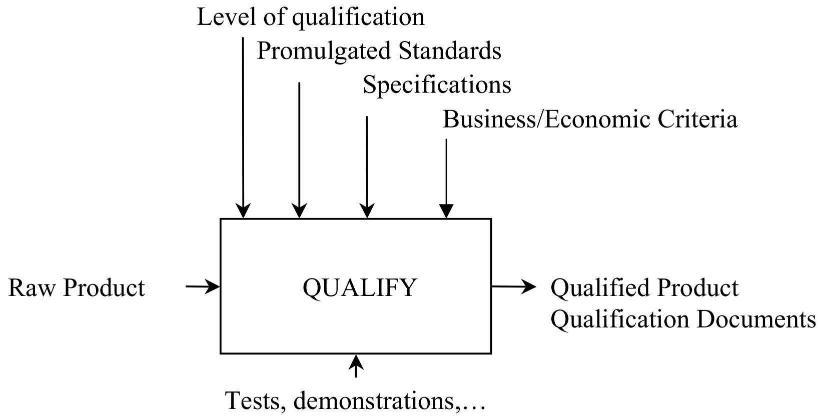
EU Directives or Regulations,

National decrees and other legal acts, and

ICAO SARPS (which are directly binding on ICAO States and that may be sometimes supplemented by regional implementation rules defined by ICAO Europe / Eurocontrol)

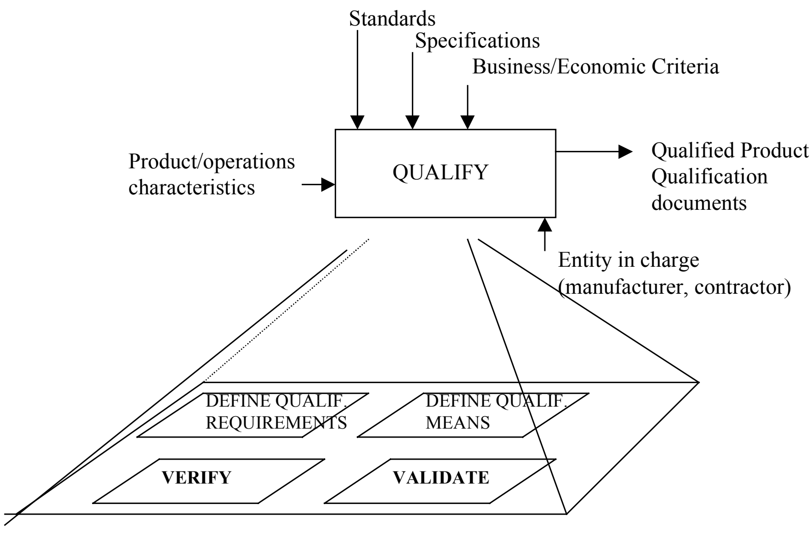
Regulations and the promulgation of standards are performed within an existing institutional/legal framework. Political, economic and social considerations are qualitative parameters that bear influence on the process.

Annex G.2.4 The qualification function

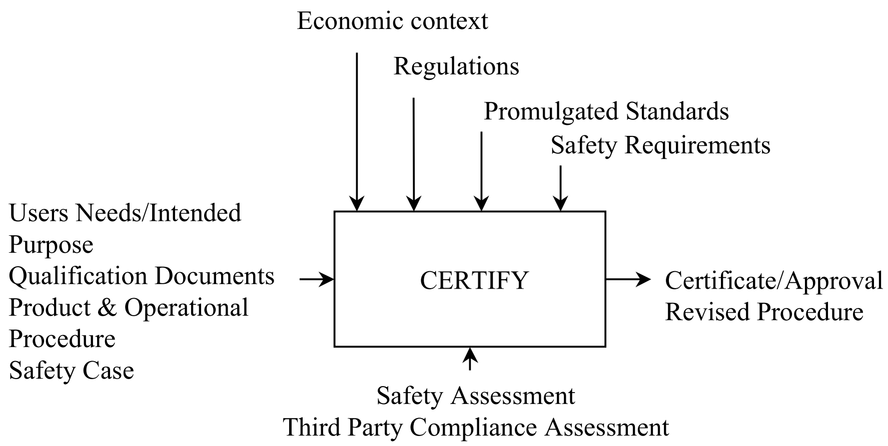


The qualification function is performed by using qualification means such as those indicated above and generally by the body in charge of producing or managing the entity (e.g. designer, manufacturer, operator, service provider). The level of qualification represents the level of proof that is to be provided to justify compliance to the requirements and that may be required by a certification body, a user or the producer. Business and economic criteria may impact the process since cost/benefit aspects are of paramount importance when defining the extent of the qualification.

Moreover, we suppose that "Validation" and "Verification" functions are included in the qualification function, as shown on the following diagram. Validation is the determination that the requirements for a product are sufficient correct and complete; verification is the evaluation of an implementation of requirements to determine that they have been met.



Annex G.2.5 The certification function



The certification function is an optional last step, and should be applied only when an independent assessment of compliance is

conducted.

There are 3 reasons why third party certification may be conducted:

- because a Safety Regulator imposes it,
- because an Economic Regulator imposes it to avoid that a proprietary solution become monopolistic,
- because the industry itself (and/or its customers) feel that it is the most cost-effective way to guarantee inter-operability by creating a common neutral assessment platform, and that the resulting label will be a stronger marketing argument than a mere manufacturer-conducted qualification.

Also, within that third party certification step, the Safety step can be optional: the certification can be limited to inter-operability and/or performance. However, when a safety certification is put in place it is generally managed independently from the other activities (it is a frequent regulatory requirement that safety issues be separately assessed) and with a wider scope: inter-operability and performance may be limited to checking the Quality Assurance policy applied by the manufacturer and the correctness of the behaviour of a technical system or piece of equipment that has been qualified on a workbench, while safety issues have to be assessed with a Total System and whole lifecycle approach, including assumptions on the way the system has been designed, and the way it is expected to be operated and maintained.

ANNEX G.3 Product lifecycle management aspects

Each of the 4 functions previously discussed plays a role in the life cycle of a product.

Five phases can be identified during the product life cycle:

- the specification & design phase related to the specifications & design of an equipment or a system, and to its integration with other equipment;
- the production phase related to the manufacturing of an equipment or a system, and to the repeated installation of the product in a series of vehicle;
- the operation phase where the operator installs and configures the product, then operates it according to equipment and installation requirements as well as operating modes, and
- the maintenance performed by the maintenance personnel, and

- Decommissioning or phase-out (that is not represented on the diagram below).

The following figure illustrates the links between the phases:

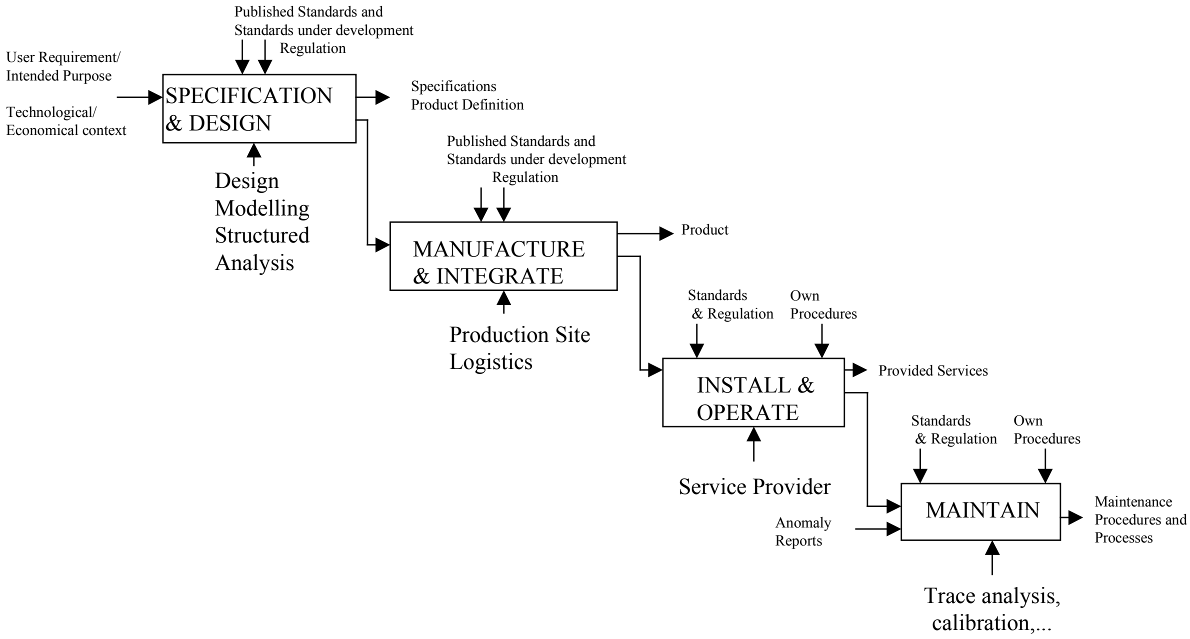


Figure AG1: Product like cycle

The minimum requirements (i.e. standards and regulation) to be used in the certification process include:

- Requirements applicable to the design of the product (equipment, system and installation): set of standards (a code of practice) applicable to that type of product so as to demonstrate an acceptable level of safety, functionality and quality of service/performance;
- Requirements applicable to the manufacture/production of an individual product: a set of standards to ensure that the individual product conforms to the design specifications;
- Requirements applicable to the operations of the product: a set of standards applicable to ensure that the procedures and processes implemented to use the product conform to an acceptable level of safety and quality of service/performance;
- Requirement applicable to the maintenance of the product; a set of standards to ensure that the procedures and processes implemented to maintain the product conform to an acceptable level of inter-operability, performance and safety.
- A separation is made in the above diagram between published standards and those standards that are still under development, since manufacturers are used to designing under published and anticipated standards in order to provide a final product that will be compliant with anticipated standards at the time they are adopted and enforced by the regulation.

The overall process of certification, including the life cycle of a product is represented by the following functional diagram:

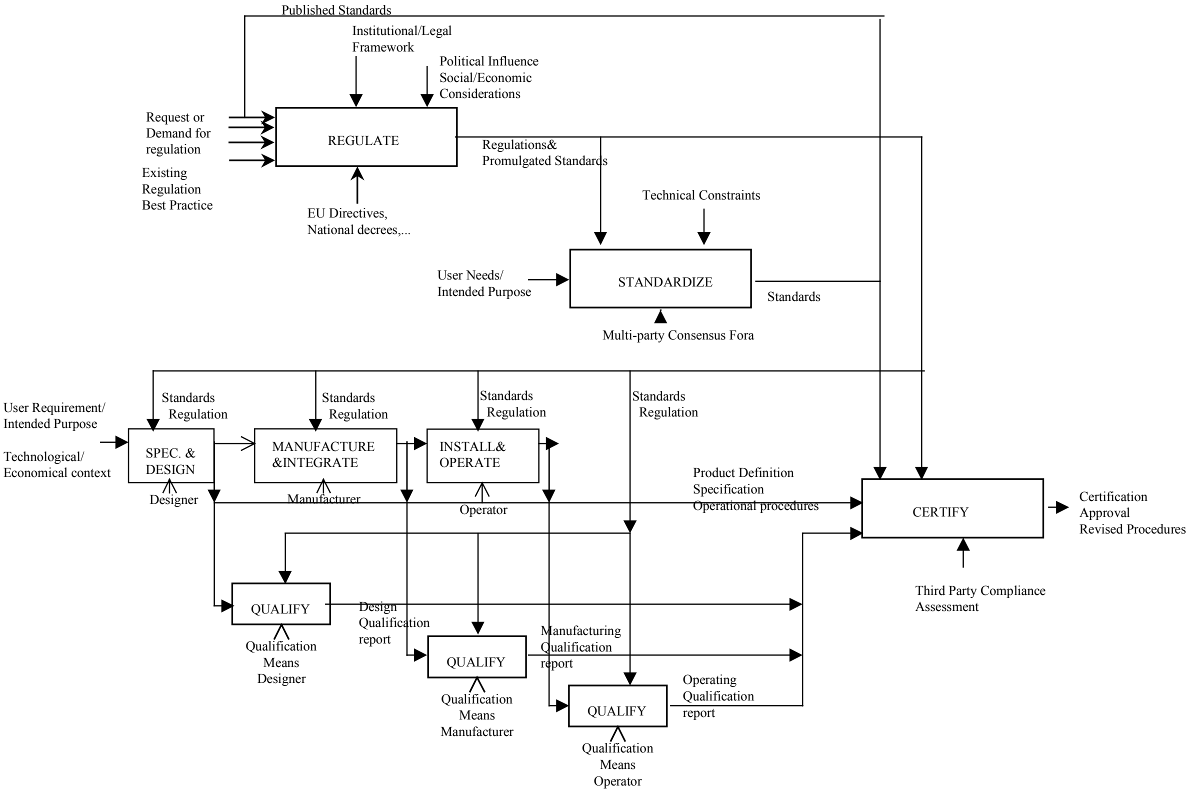


Figure AG.2: Overall process of standardisation

The certification process of a service would not be different from this one, indeed we would only need to replace the product chain by the service provider chain to develop a service certification process.