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PHARE Aeronautical Telecommunication Network (PATN) Final Report

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EXECUTIVE SUMMARY

The PHARE Aeronautical Telecommunication Network (PATN) project was set up to provide the telecommunications infrastructure for data-link services experimented in the third PHARE Demonstration (PD/3). The project was carried out as a partnership by the Centre d'Etudes de la Navigation Aérienne (CENA, acting as a project leader), the Deutsches Zentrum für Luft- und Raumfahrt (DLR), the Eurocontrol Experimental Centre (EEC), the National Air Traffic Services (NATS) / Defence Evaluation and Research Agency (DERA), and the Nationaal Lucht- en Ruimtevaartlaboratorium (NLR). PD/3 marked the conclusion of the project.

It was agreed from the start to base the developments of PATN components on the Standards and Recommended Practices that were being defined for the Aeronautical Telecommunication Network (ATN) by the International Civil Aviation Organisation. As a result from this agreement, PATN also contributed to provide its partners with an ATN validation platform. The main contribution of PATN proper in this area consisted in the development of ATN upper-layers that characterise ATN end systems. The ATN router component was actually developed in an other project, called EurATN, and integrated in the PATN architecture.

The end systems provide the interface between the communications services and the user data-link applications. Among the communications services provided by PATN is the application service element for the Controller-Pilot Data-Link Communications application standardised by ICAO. Because of the experimental nature of the data-link applications used in PD/3, it was also the responsibility of PATN to design and develop application service elements compatible with the ATN principles for the Downlinking of Aircraft Parameters, Position Reporting, and Trajectory Negotiation data-link applications.

PATN components were deployed in ground systems, and airborne systems. A complete configuration including an actual aircraft site (the DERA BAC 1-11), a simulated (static) aircraft, and ground systems was set up for PD/3 CENA. PATN components performed very satisfactorily during that demonstration. In particular, the PATN upper layers considered alone, as it was the case for the communications of the simulated air-traffic, were very efficient in terms of consumption of computing power. The reliability and performances of ATN components proper were unfortunately not correctly perceived when the actual air-ground data-link, i.e. the Aeronautical Mobile Satellite Services (AMSS) mobile subnetwork was exercised. Indeed, this service was rather unreliable during the limited time frame of the flight trials.

Beyond PD/3, PATN should be considered by the partners as a valuable basis for the experimentation of future data-link services, whereas they are mapped onto application service elements standardised by ICAO, or onto specific applications as in the case of the PHARE applications.

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1. INTRODUCTION

This document constitutes the final report of the PHARE Aeronautical Telecommunication Network (PATN) project. The PATN project was conceived to provide realistic ATN services and infrastructure to data link applications experimented during the third PHARE Demonstration (PD/3). The data-link applications and PATN components were deployed in simulated aircraft, cockpit simulator, actual aircraft, and in ground air traffic control (ATC) systems. The PATN project involved five PHARE partners: CENA, DLR, EEC, NATS (DERA), and NLR, under the leadership of CENA.

This document describes how PATN was integrated in the PD/3 architecture, and the other technical aspects of the project:

- The communication services provided to ground and air users of air traffic control,
- The architecture of interconnected equipment, known as PATN workstations, which is distributed among different air and ground sites,
- The specific pieces of airborne equipment related to the use of the Aeronautical Mobile Satellite Services (AMSS), coming from industrial sources or from PATN partners,
- The third-party ATN software pieces integrated in PATN (EurATN ATN lower layers, ATOS company ATN upper layers),
- The specific PATN developments (applications service entities -ASEs- and the associated Application Programming Interfaces -APIs- for the Controller-Pilot Data-Link Communications –CPDLC-, Position Reporting –PR-, Downlink of Aircraft Parameters –DAP-, and Trajectory Negotiation –TN- applications), which provide communication services to the PATN users.

Each PATN partner expressed their own needs in terms of ATN infrastructure for the PD/3 demonstration. Therefore, the actual implementation of PATN on each partner site may vary, in terms of:

- Deployed set of equipment (PATN workstations, Air Traffic Simulators, Cockpit Simulators…),
- Interconnection means between the different pieces of equipment (local area network, packet-switched data-network),
- Applications (for example the use of the CPDLC or PR applications to convey position reporting).

This document is organised along a site description basis, rather than as a description of the overall interconnection architecture for PD/3. The consistency of PATN interfaces (user interface, subnetwork access) was maintained in spite of the different partner needs.

Among all the PATN partners, only CENA, EEC, NATS/DERA, and NLR participated in the project until PD/3. This is why this document will not report information from DLR. DLR participated mainly in PATN ground deployment activities, until the beginning of 1997.

Chapter 2 describes the goals of PATN in term of the ATC services provided in PD/3 demonstration (2.1), and of the ATN infrastructure which it deployed in its various European partner's sites (2.2). This chapter also describes subsidiary goals fulfilled by the PATN project and the external ATN activities in which the experience gained by the team has been useful (2.3).

Chapter 3 gives a description of the PATN project in order to give a more precise view of its organisational, software and hardware boundaries, and of the relationship that it established with its environment.

Chapter 4 presents the overall architecture of the PATN deployment, whereas Chapter 5 is a description of the physical architecture deployed at the PATN sites. This architecture resulted in an ATN linking the sites of the PATN partners. CENA sites (5.1) in their air (5.1.1) and ground (5.1.2) elements; EEC site (0), in its ground (5.2.1.2) elements; NATS/DERA sites (5.3) in their air (5.3.1) and ground (5.3.2) elements, and NLR sites (5.4) in their air (5.4.1) and ground (5.4.2) elements.

Chapter 6 to 10 details the PATN deployment/integration and the involvement in the demonstrations and experimentations.

Chapter 11 to 13 represents the results, a discussion of lessons learnt and concluding remarks

2. GOALS OF PATN

2.1 PROVISION OF ATN SERVICES

The first main goal of PATN was to provide ATN communications services for ATC data-link services experimented in PHARE. These services fall into two main categories: standard and PHARE-specific services.

Standard services are services already covered by the ICAO standardisation activity in the ADS and ATN Panels. This means that operational requirements, specification and software design can be directly derived from the associated SARPs documentation, and have been validated by various implementations. The Controller-Pilot Data-Link Communication (CPDLC) service is the only standard ATN communication service implemented in PATN.

PHARE-specific services are services for which no standardisation has been conducted, and for which definition of operational requirements and specification of communication protocols have not yet taken place. The specific communication services that were implemented in PATN are the Position Reporting (PR), Downlink of Aircraft Parameters (DAP), and Trajectory Negotiation (TN) services.

Defining operational needs on the communication systems is a long and difficult process when an initial operational concept is already available. When no operational concept exists, the definition of the operational requirements tends to become a rather long, and sometimes discouraging process. PHARE was not the most adapted environment for this kind of activity. This is why the choice was made within PATN to orient service definition on standard services whenever possible.

The Frequency Change (FC) service was thus mapped onto the CPDLC application service entity. The Position Reporting (PR) service was also mapped onto the CPDLC application service entity in the CENA PD/3 architecture, as this choice could fully cover the needs for the CENA demonstration. This was not the case for the PR service in the NLR PD/3 architecture, which required a specific application service entity to be developed.

Another complementary approach consists in mapping the required services on subsets of standard services. This was originally the case with the DAP services, which could have been defined as a subset of the ADS services. However, as ADS did not support a number of data fields required by the NLR PD/3 demonstration, this approach was not considered feasible, and it was decided to consider DAP as a new service.

It was not possible to apply either of the previously described approaches to the TN (Trajectory Negotiation) services. A complete definition process was thus engaged for the TN service.

2.2 DEPLOYMENT OF AN ATN INFRASTRUCTURE

The second PATN main goal was to provide the ATN infrastructure for the PD/3 demonstrations. This involved deployment of air and ground infrastructure in the various partners' sites.

This deployment was done in two steps: PATN lower layers deployment, which involved PATN hardware and EurATN software. Then, PATN upper layers deployment, which involved upper layers communication software and PATN application service entities for CPDLC, DAP, FC, PR and TN.

The connection to the fixed and mobile subnetworks (X.25 - packet-switched data-networks) was a pre-requisite under the responsibility of each partner. The following subnetworks were used:

- the SITA ground network between fixed systems,
- the Aeronautical Mobile Satellite Services (AMSS) provided by SITA between the fixed and mobile systems (actual test aircraft and simulated air-systems).

The deployment led to the provision of a fully inter-connected ATN infrastructure between:

- CENA Athis-Mons and Toulouse (simulated air and ground networks and systems),
- DERA (aircraft and ground networks and systems),
- NLR Amsterdam (aircraft and ground networks and systems).

More details on the deployed architecture is to be found in the chapters 4, and 5.

2.3 SECONDARY GOALS

PATN also contributed to the validation of ATN standards by building on the existing validation platforms.

The lower layers of PATN consisted of the EurATN software and the equipment that had been used during ATN Internet validation by EEC and CENA.

Parts of upper layers (Session, Presentation, Association Control Service Entity (ACSE) and Dialogue control function), and the CPDLC application service entity were developed within PATN, in conformance with ATNP SARPs. These developments have been made in parallel with the SARPs definition process and have contributed in pre-validating the specification issued by the ATNP.

3. PROJECT BOUNDARIES

Because of the fact that it is made of a combination of industrial hardware and software products, together with project development and external services, the boundaries of PATN can be sometimes difficult to precisely define. This situation led at times to confusion between the PATN project and its user data-link applications.

In order to avoid such confusion, the following applies in the definition of PATN boundaries:

- PATN upper boundaries:
  - Although data conveyed by PATN was finally distributed to various air and ground applications, PATN interface was provided to the Common Modular Simulator (CMS) platform (CMS-Lite on aircraft, and CMS on ground systems). CMS was, in technical terms, the sole user of the services offered by PATN. Due to the importance of the role of CMS with respect to PATN, more explanations are given at the end of this section.
  - NLR took the decision to develop the applications in which it was involved (Downlink of Aircraft Parameters and Position Reporting) outside PATN infrastructure. In order to help NLR in its integration phases, CENA provided an additional external interface to the Dialogue Services provided by PATN. The Dialogue Services are standardised by ICAO. Standard ATN applications are all based on the Dialogue Services.
- PATN lower boundaries: they were the interfaces to the subnetworks used for PD/3 architecture.
  - SITA for ground X.25 WAN access: this subnetwork includes satellite (AMSS) links. The software interface with PATN is the Sun product Sunlink for WAN access.
  - SITA for air X.25 WAN access: in this case the interface is more complicated, as a hardware gateway has been developed by PATN-NLR team in order to interface PATN subnetwork access with AES equipment.
  - TRANSPAC for ground X.25 WAN access: this was the case for CENA where the simulated aircraft architecture was distributed between Athis-Mons and Toulouse sites, linked via TRANSPAC.
  - Ethernet LAN for site internal communication: in this case, the interface was provided by SunOS software.

PATN defined its own Software Quality Insurance procedures which have been described in the "PATN Configuration Management", and in the "Principles of Software development in PATN" documents.

The former deals with software and workstations configuration management, procedures for deliveries, defect reports, etc. The latter proposes some recommendations in software development.

The boundaries of PATN can be summarised by the following Figure 1: PATN Project boundaries, which summarises the integration of PATN in the PD/3 environment. Each component in the shaded box will be further described in this document. In addition to the ATN components, the "PATN AES interface" is a PATN deliverable.

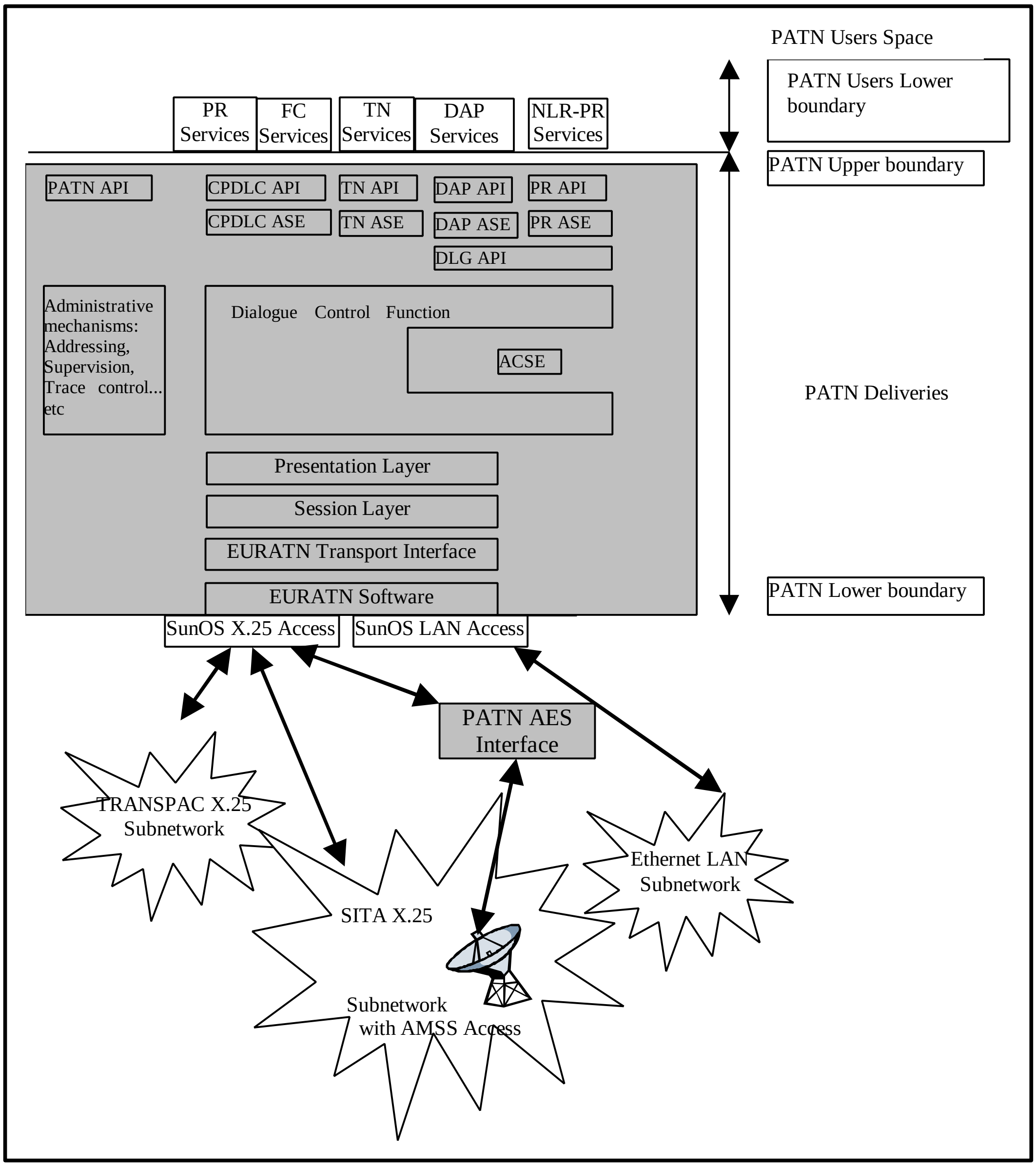

Figure 1: PATN Project boundaries

With respect to PATN, the role of CMS (Common Modular Simulator) is to map PATN external interfaces onto a uniform and consistent set of interfaces. This mapping both applies to data descriptions, and to the provided services. CMS also had an impact on the integration activities of the different sub-systems involved in the data-link for PD/3.

As far as transferred data are concerned, CMS maps the data descriptions coming from the Abstract Syntax Notation1 (ASN1) onto a set of structures, which are common to all the users of CMS. This function is one of the main reasons why CMS had to be used in the airborne environment.

In terms of provided services, CMS takes in charge the upgrade of the low level services offered by PATN to higher level data-link services. The mapping of the CPDLC (controller/pilot data-link communication) services offered by PATN to the frequency change or position reporting services is an example of such provision of services closer to the operational environment brought by CMS.

The impact of CMS on the integration activities is due to the fact that CMS implements the mapping of the application programming interfaces offered by PATN, and developed in the C programming language, to C or ADA interfaces required by CMS users. Furthermore, CMS transparently provides application programming interfaces which can be distributed: user applications, and the PATN stack can run on different machines, under different operating systems. This function was another reason why CMS was implemented in the real aircraft, where it provides a reliable interface between PATN and EFMS.

The standard programmatic interface provided to the PD/3 applications by CMS also simplified the co-ordination between PATN and user data-link applications: co-ordination only had to be maintained with CMS as far as PATN was concerned. The drawback was that this left less flexibility in the definition of the data structures transferred via data-link. This drawback did not really impact the PATN project, which could maintain the required close co-ordination with the CMS project.

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4. OVERALL ARCHITECTURE OF PATN

This part describes the whole PATN infrastructure (hardware, software, and interconnection means). It is provided on a site by site description basis.

The initial architecture, on which the PATN deployment was based involved five ground sites, three real aircraft and two simulated aircraft sites.

Ground sites were at CENA Toulouse and Athis-Mons, DLR Braunschweig, EEC Brétigny, NATS/DERA Boscombe, and NLR Amsterdam.

Real aircraft air sites were the DERA BAC 1-11 aircraft, the DLR aircraft, and the NLR Cessna Citation II aircraft.

Simulated aircraft sites (with the Multiple Cockpit Simulator –MCS- interface) were foreseen at CENA in Toulouse, and EEC in Brétigny.

This architecture was later scaled down due to the PD/3 decision to stop multi-site activities, and the DLR decision to stop its participation in PD/3. The deployment of the PATN architecture was nevertheless mostly completed, with the exception of the DLR sites. The actual deployment led to the following overall architecture:

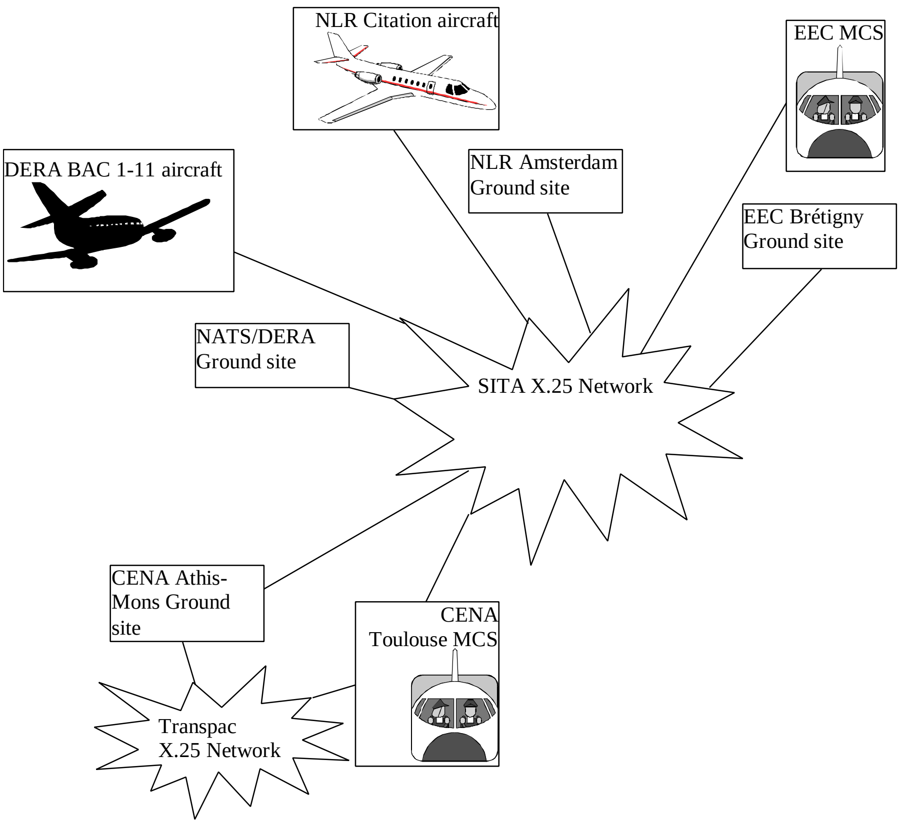

Figure 2: PATN Overall Architecture

From this overall architecture, an addressing scheme was drawn, which is fully described in the PATN Deployment plan document [Ref. 1], and which is based on the definition of administrative and routing domains, and routing areas.

4.1 PATN ADMINISTRATIVE DOMAINS

Three administrative domains were defined, directly derived from their administrative membership, that is:

- One administrative domain **AD-ENGLAND** for NATS/DERA, this domain controls
  - the NATS/DERA Air/Ground router and end system (CAA-A/G-BIS/ES), and
  - the NATS/DERA Airborne router and end system (CAA CAA-A-BIS/ES).
- One administrative domain **AD-FRANCE** for CENA and EEC, this domain controls
  - the CENA Athis-Mons Air/Ground router and end system (ATH-A/G-BIS/ES),
  - the CENA Athis-Mons ground end system (ATH-G-ES),
  - the CENA Toulouse Airborne router and end system (TLS-A-BIS/ES1), located in Athis-Mons,
  - the CENA Toulouse Airborne router and end system (TLS-A-BIS/ES2),
  - the EEC Brétigny Air/Ground router and end system (EEC-A/G-BIS/ES), and
  - the EEC Brétigny Airborne router and end system (EEC-A-BIS/ES).
- One administrative domain **AD-NETHERLANDS** for NLR, this domain controls
  - the NLR Amsterdam Air/Ground router and end system (NLR-A/G-BIS/ES), and
  - the NLR Amsterdam Airborne router and end system (NLR-A-BIS/ES).
- One administrative domain **AD-DEUTSCHLAND** for DLR: this domain controls
  - the DLR Braunschweig Air/Ground router and end system (DLR-A/G-BIS/ES), and
  - the DLR Braunschweig Airborne router and end system (DLR-A-BIS/ES).

4.2 PATN ROUTING DOMAINS

As routing domains cannot cross administrative domain boundaries, the definition of routing domains has been based on the following rule: ground ES and IS in a same administrative domain and located in the same centre, constitute one routing domain. This leads to the following:

- AD-ENGLAND administrative domain includes two routing domains:
  - RD-G-CAA ground routing domain with CAA-A/G-BIS/ES,
  - RD-A-CAA airborne routing domain with CAA-A-BIS/ES.
- AD-FRANCE administrative domain includes four routing domains:
  - RD-G-ATH ground routing domain with ATH-A/G-BIS/ES and ATH-G-ES,
  - RD-A-TLS airborne routing domain with Airborne TLS-A-BIS/ES1, and TLS-A-BIS/ES2,
  - RD-G-EEC ground routing domain with EEC-A/G-BIS/ES,
  - RD-A-EEC airborne routing domain with ground EEC-A/G-BIS/ES.
- AD-NETHERLANDS administrative domain includes two routing domains:
  - RD-G-NLR ground routing domain with NLR-A/G-BIS/ES,
  - RD-A-NLR airborne routing domain with NLR-A-BIS/ES.

- AD-DEUTSCHLAND administrative domain includes two routing domains:
  - RD-G-DLR ground routing domain with DLR-A/G-BIS/ES,
  - RD-A-DLR airborne routing domain with DLR-A-BIS/ES.

4.3 PATN ROUTING AREAS

Routing areas permit to split routing domains into smaller parts. As a routing domain belongs to one administrative domain, a routing area is contained in one routing domain.

A routing area comprises systems (ES, IS) which are all contained in one routing area.

In the case of PATN, only CENA simulated airborne network needs two routing areas.

This permits to define the following routing areas for PATN:

- RD-G-CAA ground routing domain includes one routing area with CAA-A/G-BIS/ES,
- RD-A-CAA airborne routing domain includes one routing area with CAA-A-BIS/ES.
- RD-A-TLS airborne routing domain includes one routing area with airborne TLS-A-BIS/ES1 and one routing area with airborne TLS-A-BIS/ES2.
- RD-G-ATH ground routing domain includes one routing area with ATH-A/G-BIS/ES, and with ATH-G-ES,
- RD-G-EEC ground routing domain includes one routing area with EEC-A/G-BIS/ES,
- RD-A-EEC airborne routing domain includes one routing area with ground EEC-A-BIS/ES.
- RD-G-NLR ground routing domain includes one routing area with NLR-A/G-BIS/ES,
- RD-A-NLR airborne routing domain includes one routing area with NLR-A-BIS/ES.
- RD-G-DLR ground routing domain includes one routing area with DLR-A/G-BIS/ES,
- RD-A-DLR airborne routing domain includes one routing area with DLR-A-BIS/ES.

This addressing scheme technically conforms to the recommendations of the ATNP of the ICAO. Although its definition was made at the beginning of PATN project, and important changes in the overall PD/3 architecture occurred, it did not need to be modified during the whole lifetime of the project.

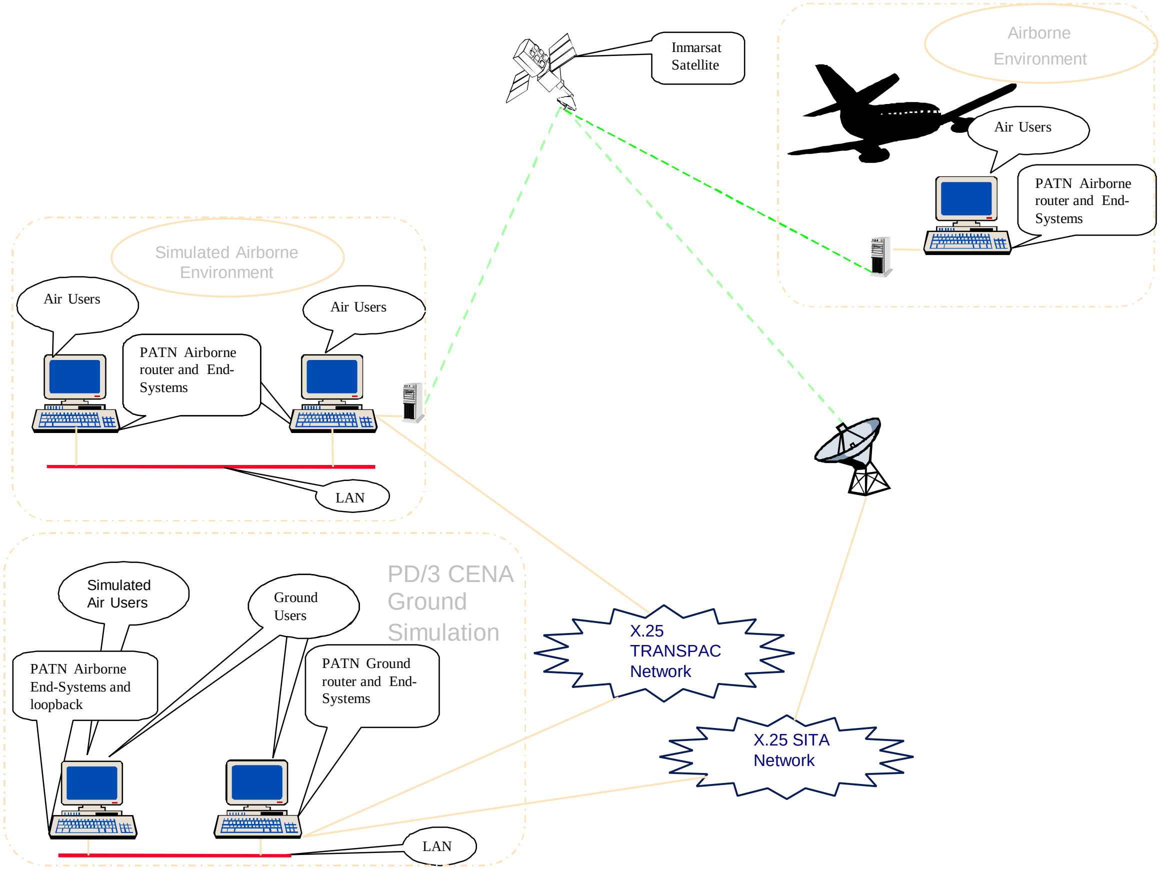

Figure 3: CENA PATN Overall Architecture

5. PATN SITES DESCRIPTION

5.1 CENA SITE ARCHITECTURE

Many intermediate configurations of the PATN platforms were used in the course of PATN deployment and integration tests. The purpose of some intermediate configurations was also to provide PATN demonstrations to various PHARE visitors. The configurations that were used during PATN deployment test activities are described in PATN deployment plan document [Ref. 1]. Examples of intermediate configurations are:

- PATN ground systems deployed at the partners'sites with CENA air simulated system (deployment tests),
- CENA air and ground systems (demonstration),
- DERA BAC 1-11 PATN air system and ground CENA system (integration tests).

We will only describe here the operational platform used by CENA for its PD/3 demonstration. This operational configuration has been designed in order to provide ATN communication services between three main environments:

- a real aircraft, the DERA BAC 1-11 aircraft,
- a simulated aircraft (MCS and EFMS) distributed between the Athis-Mons and Toulouse CENA sites,
- a traffic simulator (MASS), and a ground infrastructure located in CENA Athis-Mons.

These environments were linked together via commercial X.25 networks providing access to the satellite mobile subnetwork (AMSS) under SITA operation, and access to ground X.25 subnetwork operated by SITA and France Telecom.

More precisely:

- The real aircraft and the CENA ground site were linked via the SITA mobile subnetwork,
- The simulated aircraft and the CENA ground site were linked via the SITA ground packet-switched data network as the operational link, or Transpac (the public packet-switched data network operated by France Telecom) as a backup link.

The provided services are based on two main application service entities:

- CPDLC (Controller Pilot Data Link Communication) has been used for the provision of the Frequency Change and the Position Reporting services,
- TN (Trajectory Negotiation) has been used for the negotiation of trajectories between the pilot and the controller.

5.1.1 PATN Air equipment and architecture

5.1.1.1 PATN in the real Aircraft

The real aircraft used in the CENA PD/3 is the DERA BAC 1-11. The description of the associated ATN architecture can be found under DERA contribution to this report, in Section 5.3.

5.1.1.2 PATN in the simulated Aircraft

- Architecture and Equipment

The simulated airborne data-link equipment was distributed between both CENA sites: Athis-Mons and Toulouse.

The End System of the airborne ATN was located in Athis-Mons, and supported exactly the same PD/3 architecture as the PATN workstation in the real aircraft:

- EFMS software,
- CMS "lite" software has been used for provision of a system platform: as a subset of CMS platform, it permitted to use CMS inter-processes communication facilities and to provide distributed APIs to the user applications,
- Frequency Change services via CPDLC ASE,
- Position Reporting services via CPDLC ASE and
- Trajectory Negotiation services via TN ASE.

The router of the airborne ATN was located in Toulouse. It was connected to the ground systems either by:

- Access to the AMSS subnetwork (service provided by SITA), via the Aircraft Earth Station (AES) located in the CENA laboratory
- X.25 ground link provided by Transpac.

The latter was used in order to overcome the problems encountered during access to SITA/AMSS subnetwork.

Both router and end system were connected together via X.25 link used as a LAN between Toulouse and Athis-Mons.

The equipment involved were two PATN workstations and satellite connection equipment (Antenna and associated equipment, SDU and PATN Interface box). The workstations conformed to PATN Deployment plan recommendations and as recalled in Annex C..

The subsystems involved in the communication with the ground site via SITA/AMSS (AMSS, antenna, and ARINC Williamsburg/HDLC converter subsystems), are described in chapter 5.4.1.2 to B-3 in this document.

Both workstations implemented upper layer stack, meaning that they could play both router and end-system roles and provide PATN air services to airborne users.

5.1.1.3 Satellite access subsystems

A complete description of these subsystems can be found in Annex B: Satellite Access Subsystems.

The PATN architecture in simulated aircraft can be summarised in the following picture:

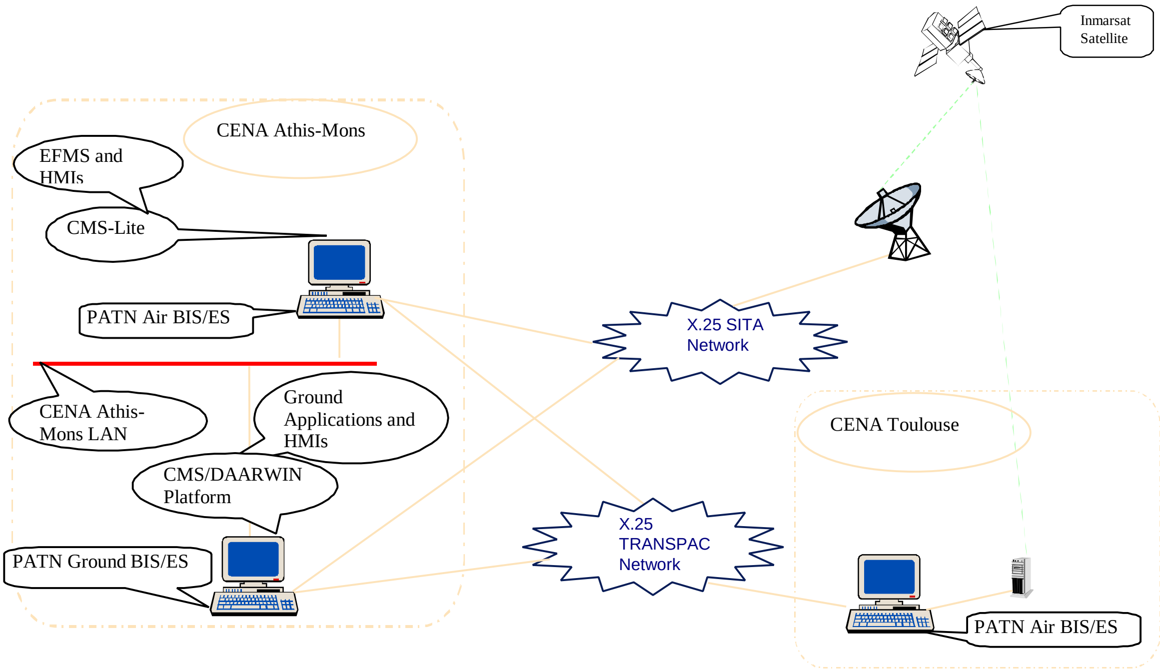

Figure 4: CENA PATN Architecture in Simulated Aircraft

<u>PATN software</u>

The software implemented in the PATN stack for the simulated aircraft is equivalent to the one installed in the real aircraft. It consists of Sunlink X.25 access and Sun access to Ethernet LAN, then on EurATN software and, last of PATN upper layers software.

The services provided to the EFMS application were the Frequency Change (FC), the Position Reporting (PR), and the Trajectory Negotiation (TN) services.

This provision is made via the Controller Pilot Data Link Communication (CPDLC) ASE for the Frequency Change (FC) and the Position Reporting (PR) services and on the Trajectory Negotiation (TN) ASE for the Trajectory Negotiation (TN) services.

A precise description of all the elements of PATN software can be found in Annex A:

PATN Upper Layers software description.

The resulting software architecture can summarised as follows:

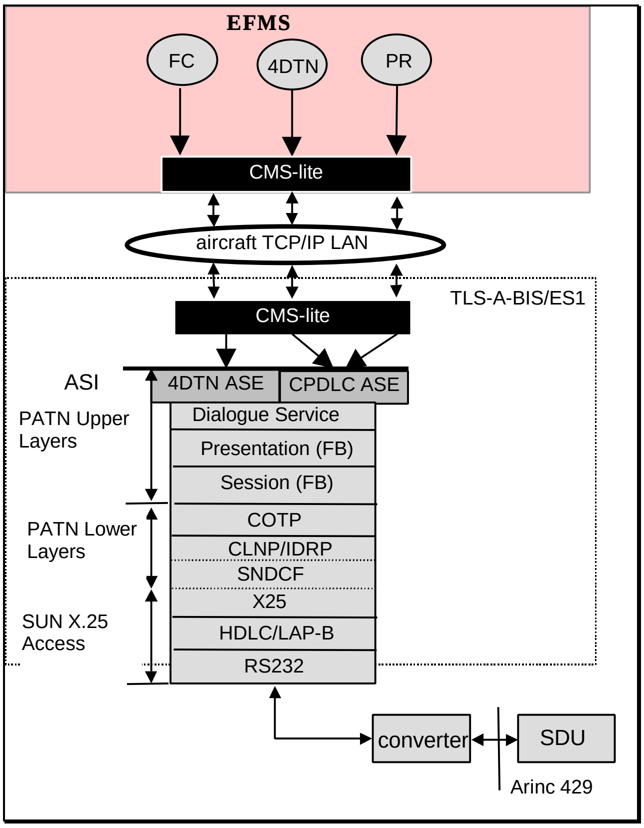

Figure 5: CENA PATN Software in Simulated Aircraft

5.1.1.4 PATN in simulated Airspace

Equipment and Architecture

The need has been expressed by PD/3 CENA to be able to provide ATN facilities in order to simulate a more realistic airspace, compared to a limited one which would have only involved a real and a simulated aircraft.

For this purpose, the ground workstation end system (ATH-G-ES) has been linked to MASS (Multiple Aircraft Simplified Simulator). It has configured in order to support an important air traffic representing more than 200 aircraft equipped with data-link facilities. This led to a PATN configuration capable of supporting 600 dialogues in parallel (200 for TN, FC, and PR).

The resources that would have been involved in the lower layer software EurATN did not permit to envisage such a configuration. Furthermore, the AMSS subnetwork capacity would not have been capable to support so many links.

The choice has been made to provide PD/3 with a limited PATN workstation. The connections to X.25 network neither the PATN lower layers were implemented in this workstation. Its architecture was as follow:

- PATN upper layers configured in order to permit its user to use PATN multi-registration facility: this meant that MASS could register 250 times on PATN stack as 250 different aircraft would have done.
- Implementation of air TN and CPDLC ASEs, in order to provide TN, FC, and PR services for the air user MASS.

- Configuration of the Presentation and Session layers in order for them to be able to manage 500 connections each,
- Provision by CENA of a delay entity, capable of simulating (real) AMSS delays,
- Provision by CENA of a loop-back entity that looped back, at the Transport layer level, any incoming traffic to the local session layer.
- Implementation of ground TN and CPDLC ASEs, in order to provide TN, FC, and PR services for the ground user CMS-DAARWIN platform.

This led to a ground CMS-DAARWIN platform both connected as a ground user

- to the simulated traffic coming from MASS via PATN ground end system (ATH-G-ES) and
- to the real traffic coming from the real aircraft via PATN ground router and end system (ATH-A/G-BIS/ES).
- to the simulated traffic coming from simulated aircraft via PATN ground router and end system (ATH-A/G-BIS/ES).

The resulting architecture can be summarised by the following figure:

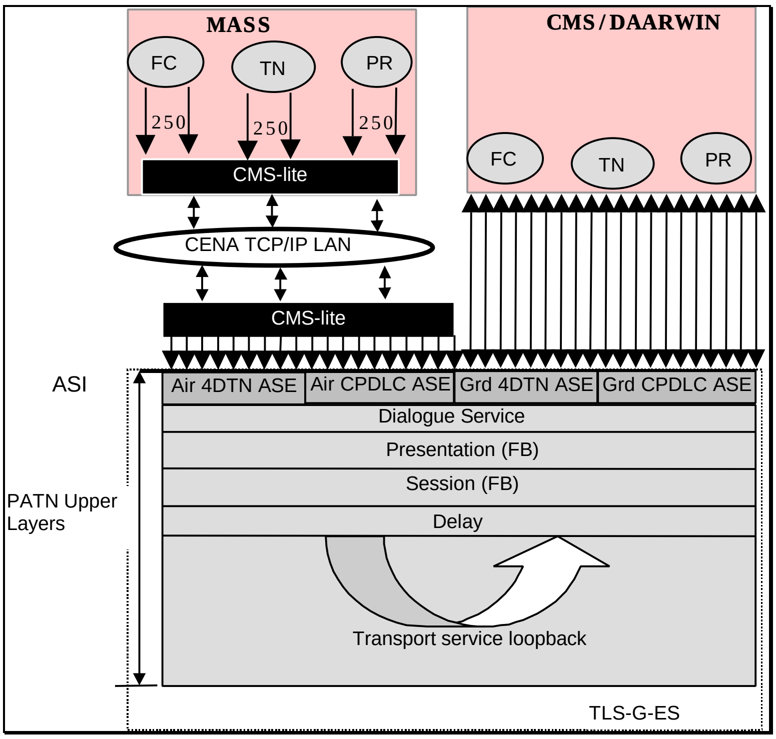

Figure 6: CENA PATN Software in Simulated Airspace

PATN software

In the case of simulated Airspace, the PATN software architecture mainly differs from other systems by the use of both air and ground facilities on the same computer.

Except from the transport loop-back and the Delay entities which were not part of PATN development, the basic bricks of software used in this configuration are the same as the ones described in Annex A:

PATN Upper Layers software description.

The main difference comes from a suited dimensioning of the OSIAM environment. This has been done in order to define an important amount of Service Access Points (SAP) on a single stack and to specify the associated application addresses in the addressing configuration file of PAT.

To summarise, the entities involved by this system were

- Two Trajectory Negotiation (TN) ASEs, one configured as ground and one configured as air,
- Two Controller Pilot Data Link Communication (CPDLC) ASEs, one configured as ground and one configured as air,
- The entity providing the Dialogue Service in the Application Layer,
- The Presentation and Session layers.
- An entity used in order to simulate various subnetwork delays, which, in this particular case was used in order to simulate AMSS delays.
- An entity providing the same service as the Transport layer, which locally looped back each connection to the Session layer.

5.1.2 PATN on Ground site

5.1.2.1 Equipment and architecture

The ground architecture was based on a PATN router and on a PATN End-system. Both are located in Athis-Mons. The PATN End-System was linked to CMS platform and has been used for provision of ATN services to applications. They consisted in Frequency Change, Position Reporting, and Trajectory negotiation services.

The workstations conformed to PATN Deployment plan recommendations as recalled in Annex C.

5.1.2.2 PATN software

The software implemented in the PATN stack for the ground infrastructure is equivalent to the one specified in PATN Deployment Plan document. It consists of Sunlink X.25 access and Sun access to Ethernet LAN, then on EurATN software and, last of PATN upper layers software.

The services provided to the CMS Platform are the Frequency Change (FC), the Position Reporting (PR), and the Trajectory Negotiation (TN) services.

This provision is made via the Controller Pilot Data Link Communication (CPDLC) ASE for the Frequency Change (FC) and the Position Reporting (PR) services and on the Trajectory Negotiation (TN) ASE for the Trajectory Negotiation (TN) services.

A precise description of all the elements of PATN software can be found in Annex A:
PATN Upper Layers software description.

The resulting software architecture can summarised as follow:

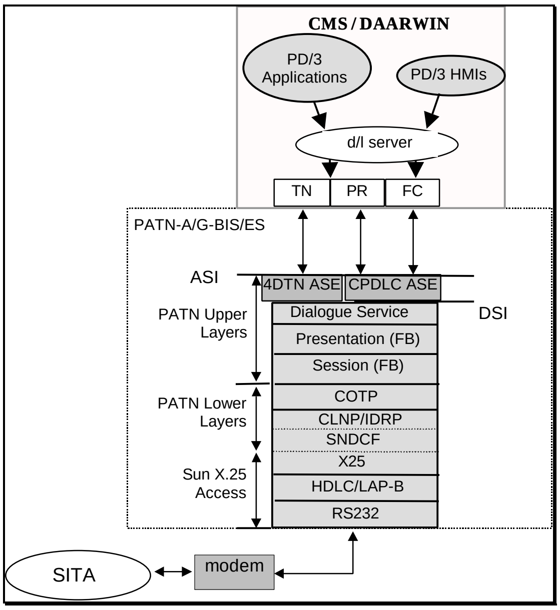

Figure 7: CENA PATN Software in Ground

5.2 EEC SITE ARCHITECTURE

Following PD3/EEC local decisions and specific objectives the choices made by EEC led to an architecture which did not conform to PATN technical choices and could not be integrated in PATN architecture. Only the first part of the PATN site deployment, which involved PATN lower layers, has been accomplished.

5.2.1 PATN Air equipped and Architecture

5.2.1.1 PATN in simulated Aircraft

Architecture and equipment

Following EEC/PD3 local decisions, no PATN Airborne workstation has been deployed in EEC/Brétigny.

5.2.1.2 Satellite access subsystems

A complete description of these subsystems can be found in Annex B : Satellite Access Subsystems.

5.2.2 PATN on Ground site

5.2.2.1 Equipment and architecture

The Boundary Intermediate Systems (BIS) have been tested between CENA in Toulouse and EEC in Brétigny. This configuration was also used in the parallel ongoing SARPs validation. Both sites used the PATN BIS. There has not been an operational application, which used the connection.

5.2.2.2 PATN software

EEC did not integrate PATN upper layers in its platform; instead, its participation in PATN Upper Layers activities has mainly been focused on the development of the Trajectory Negotiation (TN) ASE.

5.3 NATS/DERA SITE ARCHITECTURE

The NATS/DERA PATN architecture has been designed in order to provide ATN services between the DERA BAC 1-11 aircraft, and a ground infrastructure. In order to provide connectivity between the real aircraft and the ground infrastructure located in CENA Athis-Mons, the multi-site capability of PATN has been used.

Only the connection between the DERA BAC 1-11 aircraft and the CENA Athis-Mons ground infrastructure was used in the PD/3 experimentation.

The overall NATS/DERA PATN architecture can be viewed in the following figure:

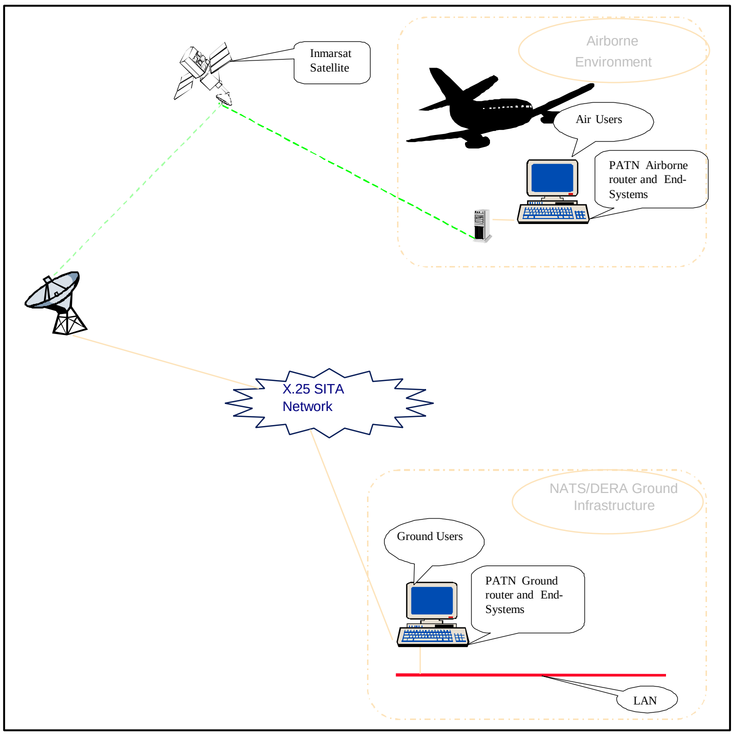

Figure 8: NATS/DERA PATN Overall Architecture

5.3.1 PATN in real aircraft

5.3.1.1 Architecture and equipment

- **<u>PATN Workstation</u>**

The aircraft PATN system is hosted in a 19" rack mounted chassis. It consists of a VME bus based Sparc20 processor card with hard and floppy discs within the chassis. External interfaces are provided for synchronous RS232, SCSI, and Ethernet. Connections are also provided for the monitor and keyboard but these are not used in flight.

The EFMS can be configured at start-up to communicate with either the onboard ATC simulator or the ground ATC via PATN. Both of these options used the aircraft Ethernet bus. Configuration changes were required within EFMS to achieve the desired communication route, which meant that EFMS would be shut down if a change of data link medium was required.

It was not deemed cost effective to install the monitor and keyboard of the PATN as a permanently in the aircraft. Instead, in flight operation and control of the PATN system was achieved using a "Powerlite" portable SUN workstation connected to the aircraft Ethernet bus. Remote login shells were created on the "Powerlite" SUN to allow sufficient operation and monitoring capability for the operator.

Satellite access subsystems

A complete description of these subsystems can be found in Annex B.

Protocol Converter: This unit was supplied to DERA by NLR under a PHARE contract to allow the PATN to communicate bi-directionally with the AMSS system. Hosted within a custom-made alloy box the system consisted of a PC with ARINC 429 and synchronous RS232 interfaces. A small flash disc was provisioned in the system to host the software and configuration files. Keyboard, SVGA screen, and asynchronous RS232 connections were available to enable software or configuration upgrades to be performed by download from a remote PC. The screen could also be used to monitor the system performance during commissioning tests. To allow this a connection was provided between the converter and a VGA resolution LCD screen already installed in the aircraft.

MCS-3000 AMSS: Consisting of four components, an SDU (Satellite Data Unit), HPA (High Power Amplifier), antenna diplexer / low noise amplifier and a low gain antenna, this Data 3 system allowed PATN to connect to the ground ATC systems via the Inmarsat Aeronautical Satellite system and SITA ground network.

The system was configured to log on to the Aussaguel GES (Ground Earth Station) via either AOR-E or IOR satellites. When once the air-ground connection was made data could be transferred to the intended destination using X25 addressing schemes.

The system is fully compliant with the requirements of ARINC characteristic 741 and provides bi-directional connections to Communication Management Units via ARINC 429 using the Williamsburg protocol.

The MCS-3000 system has a capability of using its three channels to communicate at high and low data rates as well as voice. With a low gain antenna only low rate packet-mode data services (advertised as up to 2400 baud) are possible.

5.3.1.2 PATN software

The software implemented in the PATN stack for the real aircraft consists in Sunlink X.25 access and Sun access to Ethernet LAN, then in EurATN software and, last of PATN upper layers software.

The services provided to the EFMS application were the Frequency Change (FC), the Position Reporting (PR), and the Trajectory Negotiation (TN) services.

This provision is made via the Controller Pilot Data Link Communication (CPDLC) ASE for the Frequency Change (FC) and the Position Reporting (PR) services and on the Trajectory Negotiation (TN) ASE for the Trajectory Negotiation (TN) services.

A precise description of all the elements of PATN software can be found in Annex A : PATN Upper Layers software description.

The resulting software architecture can be summarised as follows:

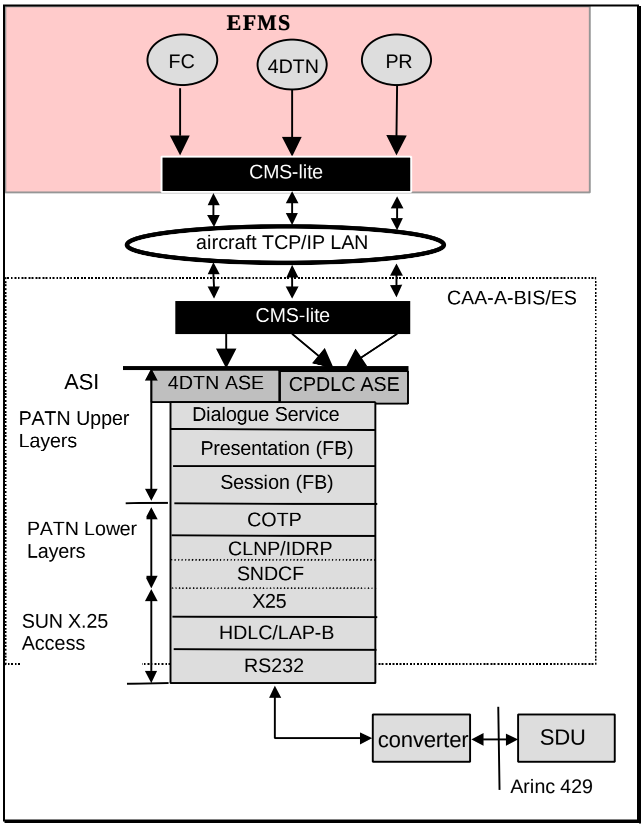

Figure 9: NATS/DERA PATN Software in Simulated Aircraft

5.3.2 PATN on the ground

5.3.2.1 Architecture and equipment

The ground architecture was based on a PATN router and end-system, located in NATS Boscombe. The PATN workstation has been used for provision of ATN services to applications consisting in Frequency Change, Position Reporting, and Trajectory negotiation.

The workstation conformed to PATN Deployment plan recommendations and as recalled in Annex C.

The CAA-A/G-BIS/ES has been connected via a leased line modem connection to SITA, providing access to the SITA X25 WAN.

5.3.2.2 PATN software

The software implemented in the PATN stack for the ground infrastructure is equivalent to the one specified in PATN Deployment Plan document. It consists of Sunlink X.25 access and Sun access to Ethernet LAN, then on EurATN software and, last of PATN upper layers software.

The services, which can be provided to the users, are the Frequency Change (FC), the Position Reporting (PR), and the Trajectory Negotiation (TN) services.

This provision is made via the Controller Pilot Data Link Communication (CPDLC) ASE for the Frequency Change (FC) and the Position Reporting (PR) services and on the Trajectory Negotiation (TN) ASE for the Trajectory Negotiation (TN) services.

A precise description of all the elements of PATN software can be found in Annex A: PATN Upper Layers software description.

The resulting software architecture can summarised as follows:

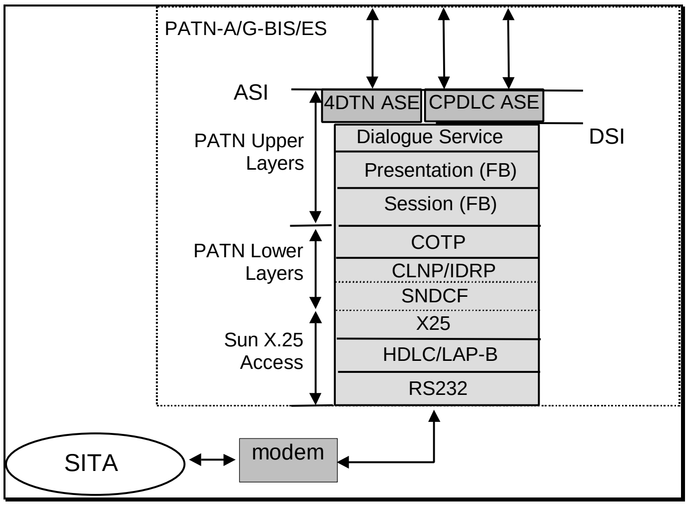

Figure 10: NATS/DERA PATN Software on the Ground

5.4 NLR SITE ARCHITECTURE

For the NLR trials two configurations were used: Laboratory test configuration and Aircraft operational configuration

- **Laboratory test configuration**

This configuration is used for the integration of EFMS, PATN, and the NLR ATC Research Simulator (NARSIM) at the NLR facilities in Amsterdam. In this configuration, the same ATN functionality is provided as for the real flight trials: full PATN upper and lower stack and the following ATN applications: DAP, PR, TN, and CPDLC.

The communication between the airborne and ground PATN workstation was realised using X25 over the NLR office LAN.

Figure 11: NLR laboratory test configuration shows a schematic diagram of this configuration.

For these trials, use was made of the same PATN hardware, as for the actual flight trials, in order to make the laboratory tests as representative for the aircraft environment trials as possible.

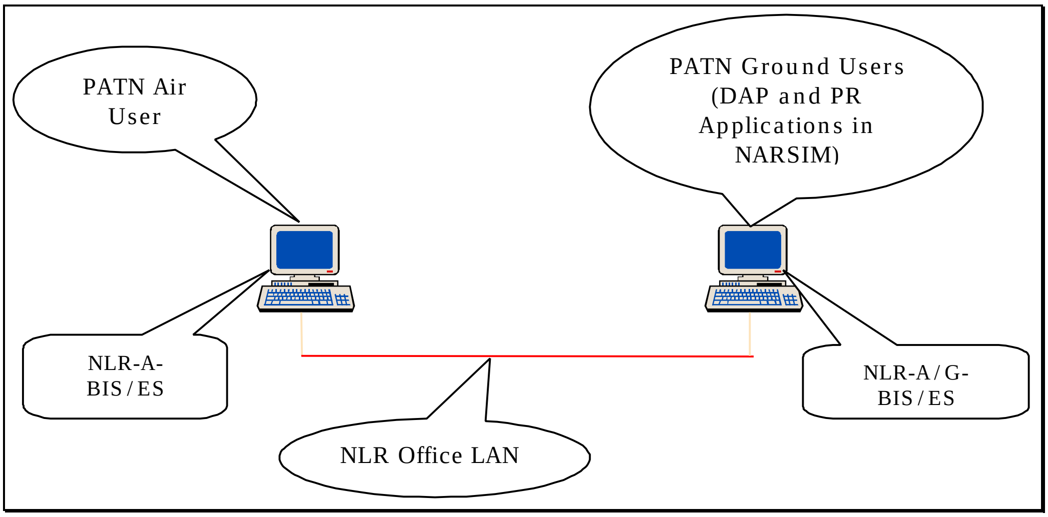

Figure 11: NLR laboratory test configuration

During some local experiments, an additional configuration was made, in which two ‘airborne’ BIS/ESs were connected to a ground BIS/ES. This configuration has only been used for some local ATN trials and has not been applied in an operational experiment.

- **Aircraft configuration**

This configuration is used for the interconnection of the NLR experimental aircraft - a Cessna Citation II - with the NARSIM ATC simulator of NLR Amsterdam, using the satellite mobile subnetwork.

Use was made of a rugged PATN workstation and converter to establish an ATN connection between the PATN air-BIS and the PATN ground BIS.

The following figure shows a schematic diagram of this configuration:

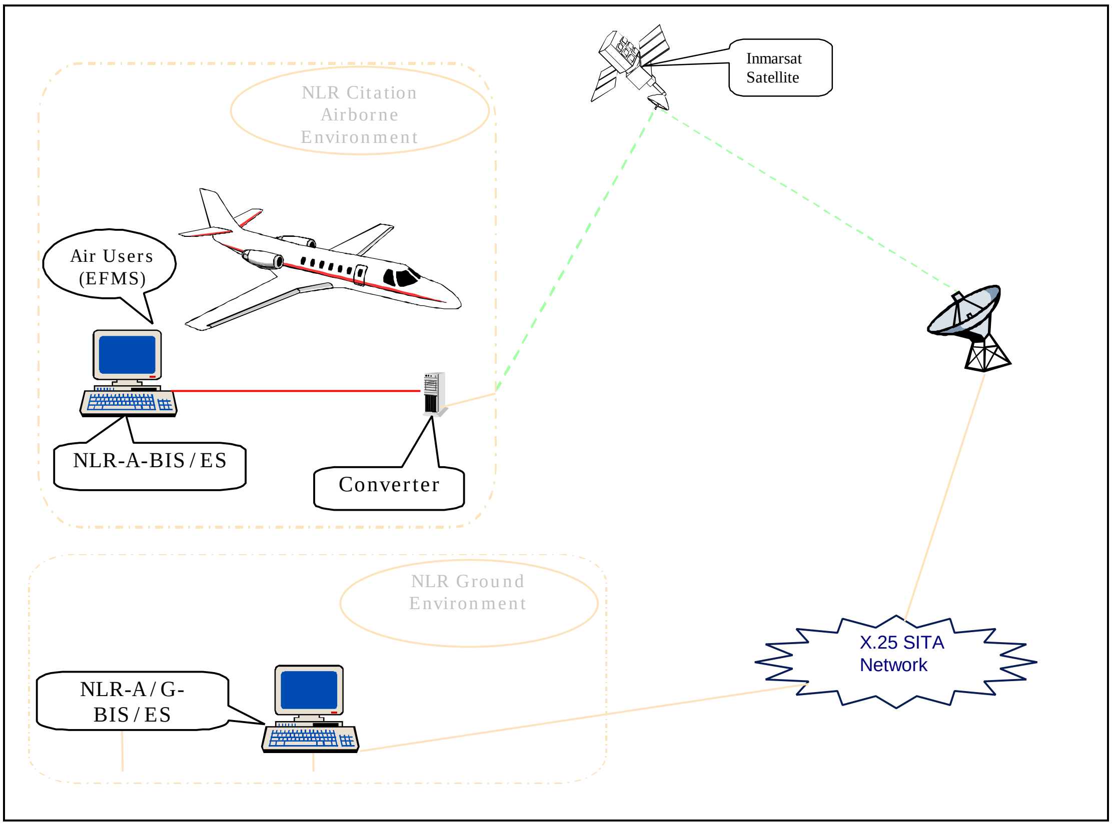

Figure 12: NLR Aircraft environment configuration

5.4.1 PATN Air equipment and architecture

In the aircraft, the following hardware has been installed:

- "Ruggedised" PATN workstation: Sun IPX
- "Ruggedised" converter, converting the RS232/HDLC interface to the ARINC 429 Williamsburg.
- Satellite Data Unit, consisting of a MCS AMSS subsystem and an antenna subsystem, providing a DATA-3 data-link services. A Class 1 AES installation utilises a low gain antenna and provides low rate packet-mode data service only.

5.4.1.1 PATN workstation

The airborne SUN workstation is based on a VME SPARC CPU-5CE industrial board from FORCE computers.

- Processor microSPARC-II with clock frequency 85 MHz.
- SPARC reference MMU
- Shared main memory of 64Mbyte DRAM
- Ethernet with DMA to SBus
- Two serial I/O ports with RS232 configuration with optional RS 422/485
- Keyboard/mouse
- Sharp TFT-LCD (resolution 1024x768)
- Trackball
- Keyboard

The SUN computer board has been installed in a suitable housing, specially designed for installation and operation in an aircraft environment, ensuring correct operation under flight conditions. This poses additional constraints on casing, connectors, EMI, and power (115V/400Hz)

5.4.1.2 Satellite access subsystems

A complete description of these subsystems can be found in Annex B: Satellite Access Subsystems.

Figure 13: NLR airborne ATN stack shows the ATN protocol stack, as it is running on the PATN SUN workstation:

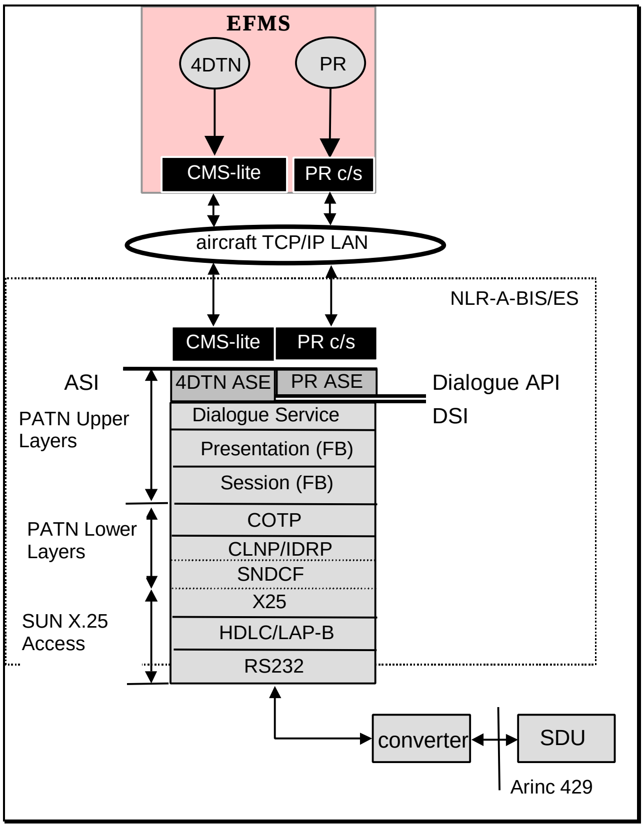

Figure 13: NLR airborne ATN stack

5.4.2 PATN Ground equipment and architecture

The ground equipment consists of one SUN workstation. This will serve as NLR-A/G-BIS/ES. The most important specifications are outlined below:

- Processor SPARC-IPX with clock frequency 40 MHz.
- Shared main memory of 64Mbyte DRAM
- Ethernet with DMA to SBus
- Two serial I/O ports
- Keyboard/mouse/display

The NLR-A/G-BIS/ES has been connected via a leased line modem connection to SITA Amsterdam, providing access to the SITA X25 WAN.

Figure 14: NLR ground ATN stack shows the ground configuration.

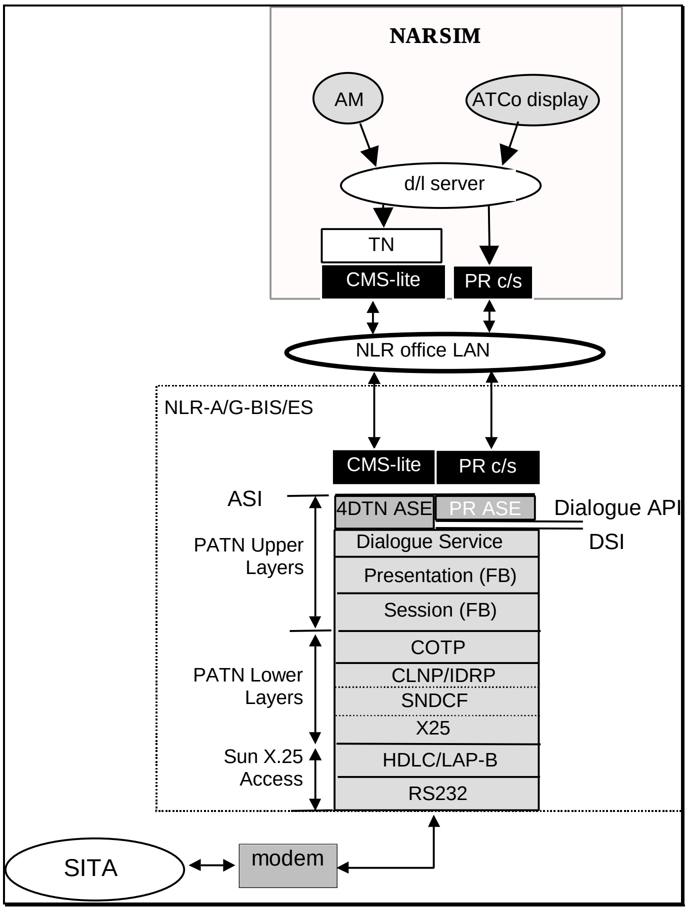

Figure 14: NLR ground ATN stack

5.4.3 PATN software architecture

Software:

The following operating system software is installed:

- Operating system: SunOS 4.1.3.b
- Environment: Motif 1.2
- Development tools: GNU C gcc-2.5.7 or higher
- SUN Patches MS2, OW3-U1, #100103-11, #100328-26

5.4.3.1 EurATN software

Following Lower layer software has been used:

SunOS:

- X25 interface: SUNLINK X25 7.0

EurATN v1.2:

- Subnetwork Access Protocol (SNAcP)
- Subnetwork Dependent Convergence Function (SNDCF)
- Connection Less Network Protocol (CLNP)
- Inter Domain Routing Protocol (IDRP)

- Connection Oriented Transport Protocol (COTP)

5.4.3.2 External networks access

The following X25 networks have been utilised during integration and trials:

- X25 over office LAN (integration configuration)
- X25 to SITA (flight configuration)
- X25 to AMSS (flight configuration)

5.4.3.3 Upper layers software

PATN upper stack version 3.0 that involves the following layers:

- Session (FastByte)
- Presentation (FastByte)
- Dialogue service

All PATN BIS/ES systems were equipped with CPDLC, DAP, PR and TN ASEs.

For the communication between the EFMS platform and the PATN, CMS-lite was used for TN and for PR, a RPC client/server mechanism was developed. For the connection NARSIM-PATN, a combination of CMS-lite and NARSIM client/server was used for TN, and just the NARSIM client/server for PR. Both CMS-lite and the client/server software are not part of the delivery of the PATN project.

6. PATN DEPLOYMENT AND INTEGRATION

This part of the document describes the different steps involved in the integration of PATN in order to provide an ATN infrastructure for PD/3.

6.1 PATN LOWER LAYERS DEPLOYMENT

This first part of PATN deployment mainly involved the lower layers of PATN, meaning that the pre-requisite for this activity was that each partner had already an access to the various subnetwork. These subnetworks were SITA/AMSS for airborne and air simulator systems, SITA X.25 for ground systems, Ethernet LAN for local area networks both in airborne and on ground, and local additional WAN, such as Transpac for CENA.

6.1.1 Ground deployment

PATN lower layers deployment was originally split in three main phases:

- ground deployment,
- ground based airborne deployment,
- flying airborne deployment.

This organisation had to be adapted due to delays in airborne equipment deliveries or unavailability of aircraft.

Only the ground deployment activities were managed as initially scheduled. Airborne deployment, with ground based aircraft, was done at the same period as upper layers deployment. An airborne deployment, with flying aircraft, was done at NLR and DERA under the responsibility of the local PATN teams.

Except for DLR, ground deployment activities were performed with all PATN partners using the simulated aircraft at CENA (including for the CENA ground deployment).

These deployment activities took place a first time using DATA-2 satellite systems, i.e. equipment conformant to the Aeronautical Mobile Satellite Services (AMSS) standards only up to the data-link layer (Layer 2 according to the ISO/OSI terminology). When DATA-2 AMSS equipment is used, the subnetwork access protocol (Layer 3 according to the ISO/OSI terminology), which is the required interface with an ATN router, has to be implemented in an external piece of equipment. This additional piece of equipment was called an extruded DATA-3 gateway. The extruded gateway inherited from EurATN also solved the problem of interfacing avionics equipment with workstations such as the one on which the EurATN software executes. Indeed, the industry-standard data connections for avionics (ARINC 429 W)are not compatible with X.25 ports available on the router. It is both an electrical and software incompatibility. When DATA-3 AMSS equipment is used, a converter box is still required to solve the problem of physical and software incompatibility of data ports on the avionics equipment and the router. This role can no longer be played by the extruded DATA-3 gateway. A specific converter was thus delivered to the PATN project by NLR to enable the connection of the DATA-3 AMSS equipment to the PATN workstations. Deployment tests with the final DATA-3 AMSS were performed as soon as the converter box was delivered by NLR.

During Ground deployment phase, each partner's ground BIS/ES (XXX-A/G-BIS/ES) was connected via DATA-2 AMSS equipment to the CENA airborne simulator (CENA-A-BIS/ES). The test suite performed is described in the PATN deployment plan document [Ref. 1].

6.1.2 Air-Ground deployment

This deployment phase only involved CENA, DERA/NATS and NLR partners, since DLR stopped its participation in PATN before starting the Air-Ground deployment and EEC had decided to install its own ATN platform on its simulator.

6.1.2.1 Air-ground deployment using DATA-2 equipment

During this deployment, the existing DATA-2 SDU equipment has been used, in combination with the PATN airborne SUN workstations. This phase proved the correct installation and configuration of the EurATN software on the SUN. This activity has been performed between the each PATN partner's ground BIS (XXX-A/G-BIS/ES) and airborne BIS/ES (XXX-A-BIS/ES).

During this task, use was made of the existing gateway PC which interconnected the SUN and DATA-2 SDU.

6.1.2.2 Air-ground deployment using DATA-3 air-ground deployment

The DATA-2 SDU AMSS service was not compliant with the OSI standards. It was gradually replaced by DATA-3. From early 1997, DATA-2 was no longer supported and PATN had to replace the SDU equipment.

The goal of this deployment-phase was to prove the correct installation and configuration of the AMSS equipment and each partner's ground BIS/ES (XXX-A/G-BIS/ES) and airborne BIS/ES (XXX-A-BIS/ES). During this phase, the correct functioning of the full communication chain between the aircraft and ground has been tested.

For each partner, the addressing information of the ground router and end system (XXX-A/G-BIS/ES) and of the airborne router and end system (XXX-A-BIS/ES) has been set up conforming to PATN addressing plan.

6.2 PATN UPPER LAYERS DEPLOYMENT

All PATN BIS/ES systems were equipped with full upper stack, including the TN, and CPDLC ASEs and, for NLR, the PR and DAP ASEs.

6.3 INTERCONNECTION OF PATN SITES

The results of deployment activities were an ATN infrastructure between CENA, DERA/NATS, and NLR PATN systems.

The following systems were connected:

- the CENA Athis-Mons Air/Ground router and end system (ATH-A/G-BIS/ES), with:
    - the CENA Athis-Mons ground end system (ATH-G-ES),
    - the CENA Toulouse Airborne router and end system (TLS-A-BIS/ES1), located in Athis-Mons,
    - the CENA Toulouse Airborne router and end system (TLS-A-BIS/ES2),
    - the EEC Brétigny Air/Ground router and end system (EEC-A/G-BIS/ES). This connectivity only involves PATN lower layers (EurATN Upper Boundaries).
    - the NATS/DERA Air/Ground router and end system (CAA-A/G-BIS/ES),
    - the NATS/DERA Airborne router and end system (CAA-A-BIS/ES),
    - the NLR Amsterdam Air/Ground router and end system (NLR-A/G-BIS/ES),

- the EEC Air/Ground router and end system (EEC-A/G-BIS/ES), with:
    - the CENA Athis-Mons Air/Ground router and end system (ATH-A/G-BIS/ES). This connectivity only involves PATN lower layers (EurATN Upper Boundaries).
    - the CENA Toulouse Airborne router and end system (TLS-A-BIS/ES2). This connectivity only involves PATN lower layers (EurATN Upper Boundaries).
- the NATS/DERA Air/Ground router and end system (CAA-A/G-BIS/ES), with:
    - the NATS/DERA Airborne router and end system (CAA-A-BIS/ES),
    - the CENA Athis-Mons Air/Ground router and end system (ATH-A/G-BIS/ES),
    - the CENA Toulouse Airborne router and end system (TLS-A-BIS/ES2),
- the NLR Amsterdam Air/Ground router and end system (NLR-A/G-BIS/ES):
    - the NLR Amsterdam Airborne router and end system (NLR-A-BIS/ES)
    - the CENA Athis-Mons Air/Ground router and end system (ATH-A/G-BIS/ES),
    - the CENA Toulouse Airborne router and end system (TLS-A-BIS/ES2).

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7. SERVICES PROVIDED BY PATN

PATN provided two kind of services: specialised services, via the use of specific ASEs (TN and DAP. PR in NLR was also a specialised ASE), or via the use of more generic ASEs like CPDLC.

Specific ASEs provide services closer to operational procedures but can only be used for a reduce set of operations: Trajectory Negotiation or Downlinking of Aircraft parameters, for example.

ASEs that are more generic provide service which are further from operational procedures. However, they provide an important set of messages pertaining to various operational procedures: CPDLC can be used for various purposes, in particular for frequency change procedures but, also, for position report.

The choice to develop generic or specific ASEs takes into account development cost and the fact that the proposed generic services should be adapted to the actual requirements. In the case of PR, the use of CPDLC meant that the PATN user was in charge of the policy according which the position should be sent to the ground. This choice was more cost effective with CMS platform as a PATN user. In other architecture, this choice has been different, which was the case at NLR, and the decision was made to develop a specific ASE.

7.1 FREQUENCY CHANGE

The FC service enables an aircraft to be handed over from one sector to the next.

The use of CPDLC ASE permits the exchange of messages involved in the Frequency Change service by providing a set of specialised messages (CONTACT [unitname] [frequency], AT [position] CONTACT [unitname] [frequency], or AT [time] CONTACT [unitname] [frequency], for example).

7.2 POSITION REPORTING

The Position Reporting service is intended to provide ground ATC systems with an accurate information of the actual aircraft position. Only the ATC centre in charge of the aircraft needs to communicate with it, but the position information could be available to users in adjacent ATC centres.

The PR service is used to put the real aircraft on the ATCo's radar display. The position reports are issued on a periodic basis, on the contrary of the Downlink Aircraft Parameters service described in 7.4, which is mainly used in an event driven mode.

In the NLR infrastructure, PR has only been required by the real aircraft, while the CENA demonstration also used it in simulated environments.

The position reporting service has been implemented in two different manners, following local choices for PD/3:

- Use of a specific CPDLC message: this is the solution adopted by CENA, mainly because it was found more cost effective. A set of messages handled by the CPDLC ASE in order to report the position of the aircraft. PATN user (CMS) used these messages on a dialogue established via the CPDLC application.
- Development of a specific ASE: this choice is the solution adopted by NLR. NLR PD3 local decision led to use a specific encoding of the data, which did not conform to PATN architectural choices. This is why the PR ASE developed by NLR is not maintained by PATN project.

7.3 TRAJECTORY NEGOTIATION

The purpose of the TN application is to support the medium term flight planning process by allowing the air and ground systems to 'negotiate' on the trajectory to be flown by the aircraft. In this context, the term 'negotiate' intends to indicate that the aircraft informs the ground system about its preferred trajectory, whereas the ground informs the aircraft about the constraints that it must take into account for conflict resolution purposes. This information exchange process shall lead to a common understanding on the trajectory that will be flown by the aircraft.

This application has been developed by EEC.

7.4 DOWN-LINK OF AIRCRAFT PARAMETERS

Currently the aircraft parameters available on the ground are fixed and a rough estimation of the actual aircraft parameters based on the known aircraft type. The DAP service is intended to provide supporting information to especially the ground Trajectory Prediction (TP) function. This information is mainly related to preferred settings that the airborne FMS uses in its own trajectory prediction. The parameters could be used by any user (including adjacent centre) that is interested in the available parameters from the aircraft. From this concept, only the ATC centre containing the aircraft in its area of responsibility will communicate with the aircraft. The ground ATC centre should use the information when the aircraft is leaving the area of responsibility of the ATC centre and enters an adjacent ATC centre in order to finish the existing dialogue.

Several ground ATC functions may benefit from accurate aircraft parameters available on the ground.

This application has been developed by NLR.

8. PATN DEVELOPMENT ACTIVITIES

8.1 CENA DEVELOPMENT ACTIVITIES

In the frame of the PATN project, the CENA team developed the PATN upper layers (Session and Presentation Layers and, in the Application Layer, the Dialogue Control Function and the Association Control Service Entity).

Then, CENA developed one Application Service Element (ASE): the Controller Pilot Data Link Application (CPDLC).

All these development took place in C-OSIAM development environment, following the agreement reached between EUROCONTROL, CENA, and the MARBEN Company. This environment has proved to be, at least for the case of CENA, very cost effective. The development of all the upper layers took 24 man.weeks, while the specification, development and test of the CPDLC application service element took 20 man.weeks.

CENA bought a licence for an ASN.1 compiler, and could act as a compilation server for ASN.1 files submitted by partners in their PATN developments. The runtime library used to encode ASN.1 data structures according to Packed Encoding Rules (PER) as specified by the ATN standards was part of the agreement with the MARBEN Company.

Following a request made by NLR concerning the difficulties encountered by its team to develop in the C-OSIAM environment, CENA developed an Application Programming Interface (API) to the Dialog service, and lent that API to the partners for the PATN project. This API was used by NLR in order to interface its ASEs without needing to develop them inside C-OSIAM environment.

8.2 EEC DEVELOPMENT ACTIVITIES

The EEC developed one application for the PATN Upper Layers: Trajectory Negotiation (TN).

Despite repetitive delays in the delivery of the specification of TN application, EEC managed to deliver it in time together with an Application Programming Interface (API).

The TN application development took much longer than initially planned. Development ended up taking about 10 months. Specifications were unclear for much too long. The teams involved in application specification, and integration hardly managed to come to common points. The PATN project suffered from this situation.

The TN ASE has been integrated in PATN (both air and ground) in order to use it in the CENA and NLR demonstrations. This integration was performed with the active support of the EEC team.

EEC’s intention was to port the TN to their own ATN end-system project, and to benefit from a greater synergy with other EEC internal projects.

8.3 NLR DEVELOPMENT ACTIVITIES

NLR developed two Application Service Elements (ASEs): Down-link of Aircraft Parameters (DAP) and Position Reporting (PR).

The DAP was intended for the improvement of the ground based trajectory predictor by down-linking actual aircraft parameters. PR was developed for the down-link of the position of the aircraft, in order to get surveillance data from the aircraft on the ATCo displays of NARSIM.

None of these ASEs were developed within the C-OSIAM development environment. Following a 3 day training course on C-OSIAM, it was felt that this environment was too complex, and development would be very time consuming. In order to reduce the risks involved, it was decided that these ASEs were to be connected directly to the PATN dialogue service.

The DAP functionality was not used by the EFMS and NARSIM during the trials.

9. PATN INTEGRATION AND TEST ACTIVITIES

9.1 CENA

PATN was involved in many CENA integration activities, which aimed at providing an ATN infrastructure to CMS for integration of the MASS simulator, of the MCS simulator, and of the CMS/DAARWIN ground system.

Integration steps involving PATN took place as follows:

- ATN systems not connected with each other, or using loop-back facilities, were provided in order to integrate user software.
- Integration with MASS was checked with a reduced version supporting only 70 aircraft of the ground end system (PATN-G-ES).
- In parallel with MASS integration, a test ground router and end system (PATN-A/G-BIS-ES) with loop-back facilities was provided in order to integrate the CMS/DAARWIN ground system.
- An airborne router and end system (PATN-A-BIS/ES) linked to the ground infrastructure via the Ethernet local area network was set-up. This connection could be switched to the Aeronautical Mobile Satellite Services (AMSS) subnetwork on demand. The final installation of the AMSS access infrastructure was achieved in Toulouse with support from NLR.

These four step took place at CENA Toulouse and involved partial integration platforms.

The next step also took place in Toulouse, but involved a copy of the complete CENA platform, except that all the components were located in Toulouse. The fixed Transpac subnetwork simulated the AMSS air-ground link.

Then the Athis-Mons infrastructure was set up, which resulted in the availability of two platforms, one for local integration and tests purposes, located in Toulouse, and the other one, used for final demonstration preparation, distributed between Toulouse and Athis-Mons.

In parallel, support for the DERA BAC 1-11 integration was provided by the CENA team, in order to investigate the problems encountered on the satellite link by NATS/DERA. This support was provided by letting part of the CENA PATN team provide on-site assistance, first to Boscombe Down airfield, and then to Brétigny airfield, and by providing ground support in Toulouse.

Testing was also conducted in Toulouse, with the DERA/NATS router and end system integrated in the CENA Toulouse airborne infrastructure.

9.2 DERA/NATS

During the integration and testing phase of the DERA task the following tasks were to be performed:

Installation of EurATN software on aircraft PATN workstation,

Installation of PATN software on aircraft PATN workstation,

Installation of CMS lite software on aircraft PATN workstation,

Installation of CMS lite software on aircraft EFMS workstation,

Test EurATN over ground SITA network,

Test EurATN + PATN over ground SITA network,

Test EurATN + PATN + CMS lite connection with EFMS over ground SITA network,

Test EurATN over AMSS and SITA network,

Test EurATN + PATN over AMSS and SITA network,

Test EurATN + PATN + CMS lite connection with EFMS over AMSS and SITA network,

This work was started in March 1998, following the release of PATN version 3.0, and was to be complete by the demonstrations in June 1998 and CENA were asked to provide help in integration and testing over this time.

During the first installation period, CMS lite was not available for installation so the EurATN and PATN software was installed with a view to testing before delivery of CMS lite. In addition, due to the short time scales available for integration effort, the EurATN software was configured only to be operated over the AMSS.

During the testing four areas of the system were found to be exhibiting problems:

AMSS subnetwork,

Aircraft PATN workstation processor,

Unpredictable nature of the EurATN / PATN tests,

The Brétigny airfield RF environment during the demonstrations.

9.2.1 AMSS subnetwork

It was found during all ground tests and subsequent flight tests that the AMSS subnetwork issued network congestion resets whenever the data loading became too large for it. This limit on data loading occurred most frequently during trajectory down-links, the largest message transmitted by EFMS.

The reset command resulted in EurATN needing to clear down and then restart the communication channel, the correct response to a reset. The effect of the reset was to reduce the data transmission rate whenever the command was issued.

9.2.2 Aircraft PATN workstation processor

The EurATN system specification defines the Sun workstation to be used as well as the version of operating system to be installed, both of which are archaic. The only processor which DERA could get authorisation to purchase was a modern Sun4m which resulted in some incompatibilities with the EurATN software.

Re-compilation of the entire EurATN software was considered unfeasible and it was subsequently found that only one file was sensitive to the processor type. When this file was updated, EurATN functioned as expected.

9.2.3 Unpredictable nature of the EurATN / PATN tests

At each stage of installation or modification of the EurATN / PATN software, tests were performed to ensure any changes had been implemented correctly and had not affected the overall system performance. These tests were the Free Text Application, acting at the top of EurATN, and the CPDLC protocol exerciser. The difficulty of each test to be analysed was compounded by the inconsistent operation of EurATN. Very little trace data was found to be available from EurATN, which did not help in diagnosing the problem.

9.2.4 The Brétigny airfield RF environment during the demonstrations

During the flight demonstrations at Brétigny, in the course of every flight at approximately 1000 feet above ground level the aircraft AMSS equipment lost contact with all satellites. In this state, no communication was possible and EurATN had extreme difficulty handling the situation. This forced a complete reset of the whole aircraft communication chain. This process took approximately 5 minutes. After the reset process was completed the aircraft was well into its demonstration scenario and had climbed to approximately 15000 feet.

9.3 EEC

EEC decided in early 96 not to go on with the PATN BIS, but to use the TAR/TTS BIS, an EUROCONTROL development. In 97 EUROCONTROL stopped all PATN (EurATN)-BIS developments. The other partners continued to use the PATN BIS.

EEC decided to use ESCAPE instead of the CMS.

For the EEC the integration consisted of three parts because of the specificity of the EEC system:

1. Interoperability between BIS: PATN (EurATN) with TAR/TTS: Did not come to a success because of differences in the SARPs compliance.
2. Interoperability between PATN Upper Layers with TES using TN as an application: Was not tested, because of lack of step 1. This step was possible at a moment in time, but was not tested.

Integration of TES/TN into ESCAPE was not done because of lack of specifications and available effort. EEC did not profit from the big integration effort for CMS, because the simulator platform was too different.

9.4 NLR

During the integration work at the laboratory, the configurations as depicted in Figure 11: NLR laboratory test configuration, and Figure 12: NLR Aircraft environment configuration were used. During the integration, the experts of the various products and systems were present at NLR. This proved to be a highly efficient approach. There was only one common goal: getting all systems to inter-operate correctly. Although work was carried until late at nights, the result was that the full communications chain from EFMS via PATN to NARSIM. This was achieved for the PR and TN applications.

Following the lab integration, all equipment was installed in the NLR aircraft, and some interoperability tests were conducted. During the test-phase a number of ground test were performed with the Citation aircraft from the hangar at Schiphol connected to the NLR PD/3 ground system at NARSIM. Use was made of test equipment running a simple aircraft model feeding the EFMS-systems with ARINC data as if the aircraft was actually flying. Thanks to the geographic location of the NLR hangar, the aircraft could remain inside with the doors open and still have a good sight onto the satellites.

Due to the PD/3 measured runs in baseline configuration at NARSIM the tests were limited to 18.00-19.30 hour and 22.00 hour onwards. Despite this limited timeframe, the tests did achieve some useful results:

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These tests were conducted from the Citation to NARSIM using the satellite mobile subnetwork, and included a simulated flight to the South from Schiphol, a 180 degree turn in Belgium airspace near the French border and an inbound flight to Schiphol.

These tests showed that we were able to do:

- set-up a transport connection with continuous Inter-Domain Routing Protocol (IDRP) information exchanges,
- perform a standard trajectory negotiation,
- down-link position reporting at an interval of 20 seconds,
- receive a formalised clearance from simulated ATC,
- down-link a pre-emptive trajectory.

During a trajectory down-link, a restart request was received, indicating network congestion. The EurATN software handled it correctly, re-establishing the transport connection, and resuming the down-link. Although experiencing a significant transfer delay, the trajectory was received by NARSIM.

Due to the low satellite throughput, a number of operational timers for PR and TN expired. These values were increased.

In the GES database of the satellite data unit, a number of GESs were installed, all of which were connected to SITA:

- Aussaguel, France (GES ID 0x67), on the Atlantic Ocean Region-East satellite (AOR-E)
- Perth, Australia (GES ID 0x131), on the Indian Ocean Region satellite (IOR)
- Laurentides (Weir), Canada (GES ID 0x03), on the Atlantic Ocean Region-West satellite (AOR-W)

At the Schiphol location, all of these were visible. Although AOR-E was the preferred satellite, it frequently happened that the connection with Perth or Laurentides was established. This only happened at the first attempt to logon to any GES. During the next logon (either manually or automatically), a connection with Aussaguel was established. This phenomenon was encountered several times.

It has been tried to enable the use of all of multiple satellites, however when a logon was made to a different GES then Aussaguel, the establishment of a transport connection failed. During the final stage of the IDRP information exchange, an ERROR-PDU was received by the airborne BIS, indicating an addressing error; connecting to a different satellite results in a different DNIC in the aircraft address.

This ERROR PDU prevented a transport connection to be established between air and ground.

This problem has been resolved by manually establishing contact to Aussaguel the GES table in the SDU, although a better solution would be to fix the IDRP problem. Difficulty here is the limited time to test with the aircraft.

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10. INVOLVEMENT OF PATN IN DEMONSTRATIONS AND EXPERIMENTATIONS

10.1 CENA

During the CENA PD/3 experimentation, PATN was involved as the unique means for provision of air-ground data-link:

- Between the MASS air traffic simulator and the CMS/DAARWIN ground platform. the provided services were Position Reporting (PR), Trajectory Negotiation (TN), and Frequency Change (FC). This provision has been made for each of the 250 required aircraft, with simulated delays corresponding to a satellite AMSS subnetwork,
- Between the MCS simulated aircraft and the CMS/DAARWIN ground platform, where Position Reporting (PR), Trajectory Negotiation (TN) and Frequency Change (FC) services have been provided to the simulated aircraft (MCS), with simulated delays corresponding to a satellite AMSS subnetwork,
- Between DERA BAC 1-11 aircraft and CMS/DAARWIN ground platform.

10.2 DERA

Two applications were to be demonstrated in conjunction with the CENA ground system, ADS and Trajectory Negotiation (with embedded Frequency Change). During the demonstration week, the link could not be made to be sufficiently reliable for use during the flight until the final day. During the flight, ADS and trajectory negotiation applications were established. A trajectory negotiation cycle consisting of:

- Down-link trajectory,
- Up-link approval,
- Down-link trajectory activation,
- Up-link sector contract approval,

was successfully accomplished and examples of frequency changes were successful.

The design of the scenario determined the number of trajectory negotiation cycles per flight, which was one full cycle to the top of climb.

10.3 NLR

NLR experienced with the Position Reporting and Trajectory Negotiation data-link applications over PATN in three flights, and one almost flight:

- 29 May 1998 (19:00): Le Bourget to Schiphol
- 3 June 1998(22:00): Schiphol to Schiphol (data-link aborted before take-off)
- 4 June 1998(22:30): Schiphol to Schiphol
- 5 June 1998(02:00): Schiphol to Schiphol

Data-link exchanges were carried out between the Citation II aircraft and the NARSIM ATC simulator at NLR, Amsterdam.

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11. RESULTS

Results presented here are classified in two categories:

- the ATN components included in the PATN infrastructure, developed for the project, and which are of interest to the PATN partners even outside the context of PD/3,
- the behaviour of the PATN developments in PD/3, since providing ATN communication services during the demonstration was one of the main objectives of PATN.

11.1 PATN SOFTWARE COMPONENTS

All the PATN partner are clearly identified as promoters of the ATN. They are involved at different levels in various projects related to data-link applications, which imply the use of ATN. For this reason, it seems legitimate to consider that PATN developments constitute an important asset for partners of the project.

Before the delivery of the PATN upper-layers, the existing ATN platforms only consisted of ATN lower layers, and were essentially laboratory prototypes. The upper-layers developed in the framework of PATN constituted the first implementation of the ATN upper-layers, at the time the standardisation was being carried out by the ATNP. The PATN project thus resulted in the first implementation of a full ATN stack, from the lower-layers to the application layer. This complete ATN architecture could serve as a basis for future projects and studies.

The involvement in standardisation of ATN upper-layers and applications for the ATNP by CENA, NLR, and EUROCONTROL was very helpful during developments of PATN. However, the challenge of implementing a Session layer, a Presentation layer, and the elements of the Application layer providing the Dialogue service to the applications was not easy to meet. Furthermore, the lack of available development environment and supporting tools in the domain of protocol implementation did not facilitate the task of PATN.

This is why an agreement was set-up between EUROCONTROL, the French DGAC and the MARBEN company. Schematically, this agreement had, as far as PATN was concerned, the advantage of providing the project with a complete development environment specialised in the implementation of telecommunication protocols. It also permitted to dispose freely of the only implementation of the PER encoding facilities available at the time when the development started, which was essential in order to conform to the ATN principles.

According to the general terms of the agreement, the development of the ATN upper layers (Session and Presentation Layers, Dialogue Control Function and Association Control Service Element) was carried out by the CENA PATN development team with the environment provided by MARBEN. These developments were delivered to MARBEN by mid-1996, and a corrected version, completely repackaged as an industrial product, was delivered back to PATN by the third quarter of 1996. These products, added to the product offer of MARBEN, have been maintained freely by that company since then, and PATN benefited from an industrial-quality component. It should be noted that the product issued from the PATN upper layers software has, since then, been widely involved in various ATN projects, like TES or ProATN. This has been an important source of pride for the whole PATN team.

11.2 RESULTS OBTAINED DURING THE CENA PD/3 DEMONSTRATION

PATN was of course deeply involved in the CENA/PD3 experimentation. Various ATN platform configurations were set up during integration and demonstration phases.

The final deployed PATN infrastructure is described in the Section 5.1 of this document. In the case of the CENA PD/3 demonstrations, it includes:

- the simulated airspace infrastructure, with MASS,
- the simulated aircraft, involving the MCS and EFMS components,
- the real aircraft, with the DERA BAC 1-11 and the CESSNA Citation II aircraft.

It must be noted that most of the interventions by the CENA PATN team during the demonstrations concerned communications with the real aircraft, i.e. configurations in which the actual Aeronautical Mobile Satellite Services air-ground subnetwork was used.

11.2.1 Air Traffic Control Simulations with MASS

The connection of the MASS-generated traffic to the PATN workstation proved its efficiency in terms of management of system resources. The PATN upper-layers (Session to Application inclusively) transparently provided a full end-system capability to the ground applications, which viewed the simulated aircraft exactly as if they were real aircraft.

The volume of air traffic simulated in PD/3 did not cause the PATN workstation to be used to its full capacity. Integration tests had shown that the PATN upper layers could successfully handle a heavier traffic.

11.2.2 MCS Simulated Aircraft

The actual Aeronautical Mobile Satellite Services air-ground subnetwork was only used between the MCS simulated aircraft and the ground systems during integration and testing activities. As problems were encountered on the quality of service of the mobile subnetwork provided by SITA, the decision was made to simulate the transmission delays of the mobile link over a ground X.25 network which had stable quality of service.

This set-up ensured that the CENA PD/3 demonstration was not disturbed by unpredictable air-ground connection resets, while keeping the operation of the full ATN stack and realistic air-ground transmission delays. This configuration proved the successful operation of the whole PATN stack.

A delay entity has been added to the PATN stack to provide the realistic transmission delays.

11.2.3 Real aircraft

11.2.3.1 Link Performance

Unfortunately, due to problems within various parts of the system, little data was available for collection that would give a proper indication of the link performance. At the time of writing, the data transfer performance for the CPDLC application was not known and only four TN transactions were recorded in sufficient detail to determine their performance.

11.2.3.2 Results

- **5/6/98** Ground test

07:51:45 Down-link trajectory of 5244 bytes

07:56:12 Up-link trajectory approval of 52 bytes

of which the down-link took 4 minutes including one network reset.

- **5/6/98** Pre-flight generation

08:12:08 Down-link trajectory of 5244 bytes

08:13:27 Up-link trajectory approval of 52 bytes

of which the down-link took approximately 1 minute with no network resets.

- **5/6/98** in flight:

08:43:02 Down-link trajectory of 1932 bytes

08:44:33 Up-link trajectory approval of 52 bytes

the split times are unknown but no resets occurred during this exchange.

- **5/6/98** Afternoon demonstration (times are ground system simulation times)

07:59:05 Down-link trajectory of 5244 bytes

08:03:14 Up-link trajectory approval of 52 bytes

the split times are unknown but this transaction did include one network reset.

The performance of the subnetwork was always subject to the occurrence of network resets during the message transaction, such that if no resets were experienced, the down-link would be completed in approximately 60 seconds. However, if a reset did occur during the down-link, then 4 minutes could elapse before the ground system received the data. On the up-link side, no resets were experienced during the measured tests and an up-link clearance occupying 52 bytes was usually completed in 30 seconds.

11.3 RESULTS OBTAINED BY EEC EXPERIMENTATIONS

PATN achieved its objectives. The PATN router and end system was produced, and the applications CPDLC, DAP and TN worked. The PATN end system was successfully integrated into the Common Modular Simulator (CMS), and experiments took place in CENA. EEC had different objectives and problems.

However, the EEC specific objectives have not been reached.

EEC did not participate to the final experimentation.

11.4 RESULTS OBTAINED BY NLR EXPERIMENTATIONS

During the NLR trials, it was found that the concept of ATN was working fine.

After a network congestion error, the transport connection was lost. PATN successfully re-established the connection.

A major problem was the extremely low throughput of the satellite subnetwork. This was outside the influence of PATN. Unfortunately, Inmarsat was not able to resolve this issue in time. PR was not affected by this but for TN, this was unacceptable.

Due to the low satellite throughput, a number of operational timers for PR and TN expired. These had to be increased, compromising their operational requirements.

During the flight trials, it was found that it took a considerable amount of time before all systems were up and running. Although during the proceeding of the trials, this process was automated as much as possible, it did remain a hot issue.

This was not particularly the case for the PATN systems and servers. All PATN software in the aircraft was started with a single command: START.

The dependency of the various systems required the start-up of systems to be synchronised. This was automated during the trials, however for the synchronisation of the simulation time between NARSIM and EFMS, it was crucial to have an R/T link.

The PR message size was 91 bytes X25 user data. The PR update rate was set to 20 seconds, which did not pose any problem. IDRP data was exchanged at an interval of 70 seconds down-link and 660 seconds up-link (message size 36 bytes at X25 level)

transfer delay for a PR message was about 10-15 seconds.

The main problem began with TN, which could have a message size of over 6 KB. This message had a transfer delay of up to 5 minutes. This high volume data-flow also affected the PR. During TN down-link, the reception on the ground of PR reports stopped. After the TN message was transferred, a large number of reports were received. The independence between the applications is not guaranteed. This interdependency is caused in the lower layers. More research is required how this can be resolved.

The operational requirements concerning the TN-message contents should be reviewed in order to reduce the amount of data per route-point. In addition, the total number of points should be reduced significantly. It was found that the trajectory as flown during the trials resulted in about 60 route-points, some at an interval of 0.5 seconds flying time. It probably does not make much sense to down-link every one of those points.

The data gathered during the trials showed the following results

Throughput.

up-link:	not enough high volume up-link data used, in order to determine throughput for up-link messages.
down-link:	200 - 300 bit/sec

Transfer delays:

TN down-link trajectory:	50 - 350 seconds: highly dependent on message size (1970 - 6800 bytes X25 user data)
TN down-link activate:	10 - 15 seconds (26 bytes X25 user data)
TN up-link constraints:	50 seconds (550 bytes X25 user data)
TN up-link approval:	15 seconds (26 bytes X25 user data)
PR up-link contract:	15 seconds (43 bytes X25 user data)
PR down-link report:	15-20 seconds (90 bytes X25 user data)

A detailed analysis of the quality of the link has not been performed. The data as provided above should only be used as a guideline.

It was found that the time of day at which the tests were performed did not significantly affect the throughput, although a detailed test was not performed to verify this.

These results were collected in three flights, and one almost flight:

- 29 May 1998 (19:00): Le Bourget to Schiphol
- 3 June 1998(22:00): Schiphol to Schiphol (data-link aborted before take-off)
- 4 June 1998(22:30): Schiphol to Schiphol
- 5 June 1998(02:00): Schiphol to Schiphol

Data-link exchanges were carried out between the Citation II aircraft and the NARSIM ATC simulator at NLR, Amsterdam.

29 May 1998 (19:00)

On the flight from Le Bourget airport to Schiphol, a return flight, after a small repair to the Cessna Citation II aircraft, the first successful data-link connection in flight to the ATC simulator at NARSIM, NLR Amsterdam was made. This included:

- Position Reporting: the contract for a PR message issued every 20 sec was initiated before take-off.
- Standard Trajectory Negotiation in the climb to waypoint ADUTO: down-link trajectory, up-link approval, down-link activate, up-link Sector Contract Approval.
- Down-link of a new trajectory in cruise.
- Pre-emptive down-link of active trajectory, just before turn to 'base leg' for runway 19R.

During this flight, also use was made of the NLR tunnel-in-the-sky display.

This flight was controlled by real ATC and was only used to test the data-link. The up-link of the approval for the second negotiation was not received in the aircraft. The EurATN software of PATN stopped just after successful, reliable operation of over an hour.

3rd June 1998

During this flight test for the PD/3 scenario showed the following results:

- the experimental system with data-link connection for PR and TN with the experimental ATC was ready within 30 minutes after start-up of the first engine.
- A power dip after start-up of the second engine caused hardware failures in the displays that could not be solved that night. The flight was cancelled.

During the day, it appeared that there was no severe damage to the system.

4th June 1998 (22:30)

These flights were witnessed at NARSIM by a number of PHARE representatives from EHQ.

This flight showed that:

- Start-up of systems decreased to less then 15 minutes.
- The data-link was up and running for about an hour when the Transport layer of the EurATN software showed errors after a number of network congestion messages. Analysis showed that these software errors were only encountered when a transport disconnect was received when a significant amount of data was still pending.
- The Position Reporting stayed alive as long as the data-link was operational.

- The down-link of the trajectory proposal (about 6596 bytes X25 data) until the receipt of the approval message in the aircraft, took about 280 seconds.
- Down-links from the aircraft were received and presented on the displays at NARSIM.
- Any up-link from the experimental ATC seemed blocked after the receipt of two spurious SCA messages in the aircraft. This occurred during the start-up process. No errors appeared in the ground system. Since NARSIM controlled multiple aircraft during this run, it is likely that an addressing error caused this failure.
- A pre-emptive trajectory down-link of 3434 bytes data required a transfer time of about 250 seconds.
- The special R/T link with the aircraft was functioning until the most southerly part of the trajectory.

5th June 1998 (02:00):

During this flight, the systems in the aircraft were demonstrated to the Airborne Programme Project Leader.

This flight showed:

- the data-link was up and running for about an hour, before the Transport layer of the EurATN software showed errors after network congestion messages.
- The Position Reporting stayed active as long as the data-link was operational. The reception interval at NARSIM varied significantly.
- The down-link of the trajectory (6809 bytes data), until the receipt of the approval message in the aircraft, took about 250 seconds.
- Down-links from the aircraft were received and presented on the displays at NARSIM.
- The automatic reboots and backup procedures of the ATN ground systems were working. Just after successful start-up of all systems, just before taxing, the ground system restarted and initiated its backup procedure.

Down-link of pre-emptive (3394 bytes) at the end of the flight took about 150 seconds.

12. DISCUSSION

This section attempts to sum up the contributions of the PATN partners on lessons learnt as a result of their participation to the project.

12.1 TECHNICAL LESSONS LEARNT

12.1.1 Development Environment

The technical choice of C-OSIAM for PATN developments could be considered as a controversial issue at some points in the project. The EEC used that environment for the development of the Trajectory Negotiation application service element, but found the training time excessive, and the acquisition of proficiency difficult. NLR had the same judgement, to the point of renouncing to use C-OSIAM for their developments. The difficulty of acquiring proficiency with this tool is not denied by the CENA experience. However, CENA still considers that using the MARBEN toolkit was a beneficial decision. CENA was responsible for a larger part of the developments, which certainly explains that developments with C-OSIAM appeared to be cost-effective in the long run. Additionally, the reliability of the PATN components based on this industrial product is hardly disputable.

The overall quality of PATN developments certainly is of great importance for partners that will keep building on PATN, or re-use the PATN infrastructure in independent data-link experiments. This is the case of CENA, which benefited from the experience acquired on the ATN upper layers, and the Controller-Pilot Data-Link Communications application. It is also the case for NLR, which successfully set up the PATN infrastructure again for a project called AATMS (Advanced ATM System).

12.1.2 Practical Requirements for Airborne Systems

NLR pointed out practical problems encountered with the actual airborne systems. The operation of the simulated aircraft, statically installed in the PATN partner's labs, had not so clearly illustrated those aspects. The NLR contribution most notably mentioned:

- In the NLR aircraft, space is a sparse commodity that introduces additional constraints to the equipment mounted inside.
- In the aircraft is it required to have both of the engines running in order to start-up the systems. It is essential to have an quick and easy start-up procedure for all systems, in order to minimise noise pollution.
- Start-up sequence: sequence of start-up of the different systems (on the aircraft as well as on the ground) appeared relevant. This requires a voice link for starting systems. This interdependency should be avoided as much as possible.
- Tweaking of the X25 parameters in order to get the satellite connection at a reliable state was very time consuming. Since satellite access is required to do this, and the aircraft is the only way this could be done, a lot of valuable time was lost here. Also, the limited availability of the aircraft limited the time to configure and test the AMSS link.
- As long as the ground speed of the aircraft is very low (at start-up or taxi), the ground speed value is invalid, which caused the EFMS not to down-link position reports. ATC was kept in the dark of the current situation.
- Synchronisation of system time is required in order to ease the data analysis of traces. It would be convenient to use standard UTC time for all systems.

12.1.3 AMSS Performances

It was generally acknowledged, even before PD/3, that the Aeronautical Mobile Satellite Services (AMSS) was not the most appropriate choice of mobile subnetwork for the use of the data-link services experimented in PHARE. The VHF Digital Link (VDL mode 2), for example, would a priori have seemed a more adapted means of communications over dense continental airspace, if only for its alleged larger capacity, and better economics. However, there was no operational VDL mode 2 service at the time of PD/3 in Europe. On the contrary, there has been an operational AMSS subnetwork for some time, and standard avionics was available to access this service.

Performances of the AMSS perceived during the flight trials were markedly below those extrapolated from previous trials, from simulation results, or gathered with the simulated static aircraft set up for PATN. The AMSS performances were clearly detrimental to what users perceived of the PATN services over the actual air-ground link. Among other effects, it caused the operational timers specified in the data-link communication requirement documents (DLCRD) to expire. The only applicable solution was to increase timer values beyond the specified range.

It was not possible to get the service provider (SITA) to improve the performances to the standard level for the AMSS in the time frame of PD/3. This is certainly not due to SITA's unwillingness to comply, but more probably to the absence of effective co-ordination between several parties involved in the provision of the AMSS. Indeed, SITA is the provided seen from the point of view of the data-link user, but the SITA service depends at least on INMARSAT, the operators of the Ground Earth Stations, and the developer of AMSS components in the Aircraft and Ground Earth Stations.

The dependency on imperfect air-ground links with mediocre performances at times also stresses the requirement for minimising the volume of air-ground transmissions. The use of the Packed Encoding Rule as the transfer syntax for the ATN conforms to this requirement.

12.2 MANAGEMENT LESSONS LEARNT

12.2.1 Duration of the Project and Diverging Interests of Partners

The PATN team was highly distributed geographically (Amsterdam, Boscombe, Braunschweig, Brétigny and Toulouse). Apart from mail or telephone conversation, co-ordination took place via monthly meeting organised in turn at each partner's sites.

The primary goal of these meetings was to synchronise the different partner's activities, and to check PATN Project progress. There was a real involvement of the local teams in the PATN project. However, the initial goal of the project, that was to provide an harmonised ATN infrastructure to PHARE, became progressively obscured as local interests took the rank over the overall project objectives.

This may have been favoured by the duration of the project, since each partner could in the mean-time get involved in internal projects with objectives related to those of PATN. This was particularly the case of EEC, which got involved in their Trial ATN Router / Trial Transport Server / Trial End System (TAR/TTS/TES) project. This project resulted in a router/end system which had most of the functions of the PATN component. There was however no reason to abandon the initial objective of an overall PATN infrastructure. The decision by the project leader not to deviate from this objective led to strong criticism by the partners and was difficult to justify at times. The situation brought up by diverging internal interests thus led to unnecessary frustration in the course of PATN, in spite of the achievements of the project.

12.2.2 Ambiguous relations between PATN and PD/3

Some decisions were taken, at the PHARE Co-ordination Committee, or at PD/3 local level, which contributed to break the cohesion in the project. This was in particular the case with the decision taken by EEC to abandon the use of PATN in their PD/3 demonstration. Such a decision was bound to impact PATN, but it was not discussed with the management of the PATN project management before it was taken.

The PATN project management was not able to refuse technical choices locally made by partners, and which went against overall PATN guidelines. This was the case with the decision of NLR to use basic encoding rules (BER) for transferred data instead of packed encoding rules (PER), which was proved to be technically less efficient, and which obliged PATN to manage in its configuration unmaintained freeware tools.

Less tensions would have been generated if the project management had felt more responsible for this type of technical choices, and if these choices had been fully supported by the PHARE management.

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13. CONCLUSIONS

The PATN project met its goal of providing a complete telecommunications infrastructure that could be used to support the data-link communications for PD/3, and which conformed to the standards for the Aeronautical Telecommunication Network (ATN). The PATN infrastructure was successfully deployed in fully interconnected air and ground sites by the participants of the project, in time for integration with user applications for the CENA/PD3 demonstration, and for the NLR experiments, both in the air and ground sites. The final deployment involved:

- 2 actual test aircraft (the DERA BAC 1-11, and the NLR Citation II),
- a simulated aircraft at CENA,
- 4 ground sites (at DERA/NATS, CENA, the Eurocontrol Experimental Centre, and NLR)

PATN was able to provide the first implementation of a full ATN communication stack, including the upper-layers, which were in the process of being standardised by the International Civil Aviation Organisation at the time of PATN developments. The PATN communications stack includes one ATN-compliant Application Service Element (ASE) for the Controller-Pilot Data-Link Communications application, and PHARE-specific ASEs for the Trajectory Negotiation, Downlink of Aircraft Parameters, and Position Reporting applications.

The ATN components proper behaved satisfactorily in the demonstration. This result confirmed the validity of ATN principles, of which PATN partners are proponents. However, a number of problems were encountered in communications with the actual aircraft. These problems could be attributed to the inconsistent quality of service of the Aeronautical Mobile Satellite Services (AMSS), which constituted the only possible link between the actual aircraft and the ground systems. This restriction to the success in the use of PATN underlines the importance of having the providers of mobile subnetwork services efficiently react to the problems notified by the ATN users. Indeed, this situation was not due to the particular context of PD/3, nor to the experimental nature of the PATN developments.

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14. RECOMMENDATIONS

Encourage project management decisions that conform with the initial project objectives, or alterations of the project objectives negotiated by all the partners of the project. It is necessary to counter-act local preferences of partners with an acknowledged authority.

Give aeronautical users of mobile subnetwork an institutional correspondent to report problems with the quality of service of the subnetworks, and authority to obtain corrections in case of non-standard performances. This would probably imply a type of co-ordination between entities involved in the provision of the subnetwork services when the chain of responsibility is as complex as for the AMSS.

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15. ACKNOWLEDGEMENTS

The members of the distributed PATN team were:

- Richard Espin for DERA/NATS,
- Rudiger Ehrmantraut and Laurent Morel for the EEC,
- Erik Jan Hartlieb for NRL, with support from other NLR participants,
- Agnès Leclercq, Mathieu Jean and Gérard Mittaux-Biron (PATN Project Leader for the latter part of the project) for CENA.

The former PATN Project Leader, Boudewijn Overgaauw, gave PATN the basis and strict directions which finally made the project a success.

The maintenance of the EurATN software was terminated at the end of the project: this was critical for PATN. The knowledge of EurATN was mainly with the EurATN consortium members, but as no contract existed for support to PATN, it was not possible to ask them for assistance. During PATN installation and integration, most of the difficulties encountered came from the satellite subnetwork, with an important impact on EurATN software and configuration. We would like to thank SOFREAVIA (Patrick Ky, Jean-Paul Doré and Florent Martinez, among others) for their help, patience and quick and accurate responses each time we sent them SOS messages on the EurATN part.

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16. GLOSSARY

ACSE	Association Control Service Element
AES	Aircraft Earth Station (AMSS)
AMSS	Aeronautical Mobile Satellite Services
AOR-E	Atlantic Ocean Region – East (INMARSAT satellite)
AOR-W	Atlantic Ocean Region – West (INMARSAT satellite)
API	Application Programming Interface
ARINC	Aeronautical Radio Incorporated
ASN 1	Abstract Syntax Notation, One
ASE	Application Service Element
ATC	Air Traffic Control
ATCo	Air Traffic Controller
ATN	Aeronautical Telecommunication Network (ICAO)
ATNP	ATN Panel
BIS	Boundary Intermediate System (a class of router)
CMS	Common Modular Simulator
CPDLC	Controller-Pilot Data-Link Communications
DAARWIN	Distributed ATM Architecture based on RNAV, Workstations, Intelligent tools, and Networks
DAP	Downlinking of Aircraft Parameter
DLCRD	Data-Link Communication Requirement Document
DMA	Direct Memory Access
DRAM	Dynamic Random Access Memory
EFMS	Experimental Flight Management System
EMI	ElectroMagnetic Interference
ES	End System
EurATN	European ATN
FC	Frequency Change
FMS	Flight Management System
GES	Ground Earth Station (AMSS)
HDLC	High Level Data link Control
I/O	Input / Output
ICAO	International Civil Aviation Organisation
IDRP	Inter-Domain Routing Protocol
IEC	International Electrotechnical Commission
IOR	Indian Ocean Region (INMARSAT satellite)

IS	Intermediate System (router)
ISO	International Standardisation Organisation
LAN	Local Area Network
MASS	Multiple-Aircraft Simplified Simulator
MCS	Multiple Cockpit Simulator
NARSIM	NLR ATC Research SIMulator
OSI	Open System Interconnection
PATN	PHARE Aeronautical Telecommunication Network
PD/3	Third PHARE Demonstration
PDU	Protocol Data Unit
PER	Packed Encoding Rules
PHARE	Programme for Harmonised of ATM Research in Eurocontrol
PR	Position Reporting
ProATN	Prototype ATN
SARPs	Standards and Recommended Practices (ICAO)
SDU	Satellite Data Unit (AMSS)
SITA	Société Internationale de Télécommunication Aéronautique
TES	Trial End System
TN	Trajectory Negotiation
Transpac	Name of the public packet-switched data network operated by France Telecom
VDL	VHF Digital Link
WAN	Wide Area Network

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PD/3 Data Link Communication Requirement Document - for Position Reporting application.

Annex A. PATN Upper Layers software description

A-1. INTRODUCTION

PATN upper layer software conforms to the ATN architecture defined by the ATNP of the ICAO. It consists of

a) a OSI standardised Session layer, in its simplified version.

b) an OSI standardised Presentation layer, in its simplified version.

c) an Application Layer, which also conforms to the OSI architecture.

The developments have been made under the OSIAM product that offers full facilities for events management between protocol entities and which also offers tracing and debugging facilities. The structure of the software development also facilitated the software product management, which lowered the costs of development in PATN.

PATN upper layer software has been developed inside OSIAM product, following an agreement passed between EUROCONTROL, the French DGAC and the ATOS (formerly MARBEN) company.

This agreement stated that the MARBEN company provided EUROCONTROL with a free license of its development environment OSIAM and of its PER encoding library. MARBEN also provides corrective maintenance on these development for free until the end of PHARE.

The counterpart was that the upper layer software of PATN ranging from the Session Layer to the Application layer (excluding the ATN ASEs) became MARBEN's property and was included in its products.

This agreement has, in a first place, permitted to use, in PATN project, an industrial and well maintained product in the upper stack of the ATN.

As MARBEN has included these developments in its product and derived many other developments from them, it has permitted to obtain, as PATN a product which has been widely used, tested. This guarantied the robustness of PATN software.

The ATN ASEs which have been developed outside this agreement are the ATN ASEs used by PATN users. They are CPDLC ASE, TN ASE, PR ASE and DAP ASE.

These ASEs have been developed by various PATN partners: CENA developed the CPDLC ASE, EEC developed the TN ASE and the NLR developed the PR and DAP ASEs.

Due to specific technical choices made during their development, which went against the technical choices made by PATN project, and with the agreement of the PCC Phare Co-ordination Committee, the PR and DAP ASEs are not part of PATN deliveries. As some other PATN development like the Dialogue API, the Transport loop-back entity and the Delay entity developed by CENA, they constitute local partner development, but they have not been taken into account in PATN configuration management.

A-2. EURATN SOFTWARE

PATN lower layers was based on EurATN software. This software has been developed under a EUROCONTROL contract and was provided to PATN by EurATN consortium.

EurATN implements the lower part of the ATN communication stack: Transport and Network layers and Convergence sub-layers used for access to various subnetworks.

The subnetworks used in the frame of PATN were: Ethernet LAN for intra-site exchanges, X.25 for inter-site exchanges on ground sites, and AMSS for air-ground exchanges on air sites.

In the case of End-Systems, EurATN was configured in order to provide only access to subnetwork, without routing functionality's, while on Intermediate-Systems both subnetwork access and routing functionality were implemented.

Apart from the management of priority at the Transport service interface, EurATN software conforms to ATNP ICAO SARPs Package 1 for the internet.

The non conformance concerning the priority parameter leads to a "default" priority provided by EurATN software both for incoming and for outgoing connections. In the case of implementation of ASEs strictly conforming to ICAO SARPs Package 1, which would check if the received priority conforms to the expected one, this would lead to interoperability problem.

In the case of PATN, only one ASE is directly derived from the SARPs, i.e. CPDLC, but it does not implement the check on the received QOS (quality of service) on incoming connection, which is the case with most implementation of ATN upper layers tested until now in CENA laboratory.

Concerning the other ASEs, as no value has been specified for the priority parameter, the default value used by EurATN should not lead to interoperability problem.

A-3. PATN SESSION LAYER

The Session layer is, conforming to the ISO model of the OSI, in charge of co-ordinating the communications between two end systems. Its precise definition can be found in [Ref. 4], [Ref.5], and [Ref. 6] documents.

It manages the synchronisation of the exchanges (which can be half or full duplex), it also permits to define synchronisation points in the exchanges, allowing the users to switch between sub-dialogues and to resume the interrupted dialogues at specific agreed points.

It also permits to restart a faulty exchange at specific agreed points.

Another important service offered by the Session layer is the possibility to release a connection instead of abruptly breaking it, avoiding so the risk of losing data in transfer.

Last, the Session layer implements the possibility to reuse the same Transport connection by two consecutive Session connections established by the same end users.

The Session layer can be customised at the beginning of the connection establishment, by specifying the set of the implemented functionality under the form of functional units.

From these characteristics, only the possibility to reuse the same transport connection for two consecutive Session connections was interesting in the frame of the ATN.

Furthermore, the services provided by a "classic" Session layer leads to an important amount of different Protocol Data Units (PDUs) exchanged by the protocol machines. As the ATN will also be implemented in aircraft, where software should pass strict certification tests, the implementation of unused software was not acceptable.

This is why an amendment has been provided to the Session layer in order to provide an enhanced version of the protocol.

These enhancements permit the limitation of the set of services to the opening of a connection, the data transfer on an opened connection and the abortive closure of a connection.

Another enhancement of the protocol is that the connection over the Transport layer can be established much quicker than with a "classical" Session and with much less exchange of data. The overhead induced by the Session protocol during connection establishment phase is of one byte, in each direction.

Last, the data exchanges on an established connection do not involved any overhead induced by the protocol.

CENA partner developed the Session layer in order to provide PATN with a realistic ATN environment. The development conforms to ICAO SARPs version 2.0 of the ATN Package 1.

A-4. PATN PRESENTATION LAYER

The Presentation layer is, conforming to the ISO model of the OSI, in charge of co-ordinating the syntax of the data exchanged between two end systems. Its precise definition can be found in [Ref. 7], and [Ref. 8] documents.

The services provided by the Presentation Layer are mainly oriented in the possibility to negotiate the syntax used to encode the exchanged data.

In the frame of the ATN, only one syntax is used: ASN.1 PER (cf. [Ref. , for packed encoded rules.

The ASN.1, as specified in [Ref. 9], [Ref. 10], [Ref. 11], [Ref. 12], and [Ref. 13] documents, defines a syntax which can be used in order to specify the data which are to be exchanged between two different implementation of a protocol stack.

Encoding rules, as specified in [Ref.14], and [Ref. 15] documents, defines the set of rules which are used to transform the data in order to transfer them on the communication path. The PER (Packed Encoding Rules) set, compresses the information to be transmitted using well known rules, limiting so the amount of data actually transferred.

Once specified under this syntax, the definition are provided to an ASN.1 compiler which generates, from these definitions, both the data structure (in C language) and the C functions which will encode the structure once fed with the actual data in order to transfer them in the Presentation Protocol Data Units.

This mechanism guaranties that any couple of implementations which uses ASN.1 syntax with the same set of encoding rules will be able to communicate and will be able to understand the data transferred.

As for the Session Layer, in order to eliminate the need for unused mechanisms, and to provide an enhanced version of the protocol, an amendment has been provided to the Presentation layer.

The services offered by the Presentation layer are directly mapped on their Session layer equivalents: they are limited to the opening of a connection, the data transfer on an opened connection and the abortive closure of a connection.

Another enhancement of the protocol is that the connection over the Session layer can be established much quicker than with a "classical" Presentation and with much less exchange of data. This is mainly linked to the simplification of the syntax negotiation mechanisms. The overhead induced by the Presentation protocol during connection establishment phase is of one byte, in each direction.

Last, the data exchanges on an established connection do not involved any overhead induced by the protocol machines.

CENA developed the Presentation layer in order to provide PATN with a realistic ATN environment. The development conforms to ICAO SARPs version 2.0 of the ATN Package 1.

A-5. PATN APPLICATION LAYER

A-5.1. STRUCTURE OF THE APPLICATION LAYER

The upper layers of PATN conform to the ATN SARPs specified in [Ref.16] document and, with this respect, define a communication profile that consists of the Session and Presentation layers as previously defined, and of an Application layer containing ASEs and a Control Function (CF).

The ASE is an element engineered to perform a required task. As described in [Ref. 17] document, two or more ASEs may be combined, together with a CF to co-ordinate their operation to form an Application Service Object (ASO). In turn, an ASO may be combined with other ASOs or ASEs with a CF to form larger ASOs. The Application Element (AE) is the outermost ASO.

In the case of PATN four Application have been defined: TN, DAP, PR et CPDLC. Two different architectural choices have been taken for the implementation of PR services: the use of a specific ASE, which is the implementation chosen by NLR, and the use of CPDLC services, which is the choice of CENA.

A-5.2. DIALOGUE CONTROL FUNCTION

The Dialogue Control Function (CF) offers the Dialogue Service (DS). This abstract service, defined in [Ref. 16], is used by the PATN ASEs to interact with the UL communications service. That is, the DS is the combination of specific internal primitives made available by the CF at the lower boundary of the PATN ASE - it is the application's “world view”. In order to provide this service, the CF uses the services of ACSE.

The set of primitives which represent the Dialogue Service available at the upper boundaries of the PATN ASO, the set of internal primitives made available to the PATN ASEs, in order to interface them on the communication provider, together with specific internal mechanisms (mapping between application names and ATN addresses, synchronisation of PATN ASEs and the Presentation layer,...etc) constitute the Dialogue Control function. In order to provide access to ASEs developed outside the PATN infrastructure (DAP and PR), the Dialogue Control function has also been provided with external APIs.

The development of the Dialogue Control Function has been done by CENA, in the frame of PATN.

A-5.3. APPLICATION SERVICE ELEMENTS AND APIS

- **ASSOCIATION CONTROL SERVICE ELEMENT (ACSE)**

The ACSE is an ASE that provides basic facilities for the control of an association among communicating application-service entities (ASEs). These facilities include: establishment of an association (A-Associate primitives) release of an association (A-Release primitives) and abortion of an association (A-Abort primitive, in case of user initiated abort, or A-PAbort primitives in case of communication provider initiated abort). The ACSE includes four optional functional units. One functional unit provides additional facilities for exchanging information in support of authentication during association establishment without adding services. Although implemented in PATN, this facility is not used in PATN. The optional context negotiation functional unit allows multiple contexts to be offered during association establishment. This facility is not used in PATN. The service definition of the ACSE implemented in PATN is compatible with X.217 | ISO/IEC 8649.

- **CONTROLLER PILOT DATA LINK COMMUNICATION (CPDLC) ASE**

<u>OVERVIEW</u>

The CPDLC application allows data link communication between controllers and pilots.

The CPDLC application provides the capability to establish, manage, and terminate CPDLC dialogues between ATS ground and aircraft system peers. Once a dialogue is established, CPDLC provides for controller/pilot message exchange.

The CPDLC application also provides the capability to establish, manage, and terminate CPDLC dialogues between two ATC ground system peers for the purpose of ground/ground forwarding of a CPDLC message.

The functional model of the CPDLC ASE is shown on the following figure:

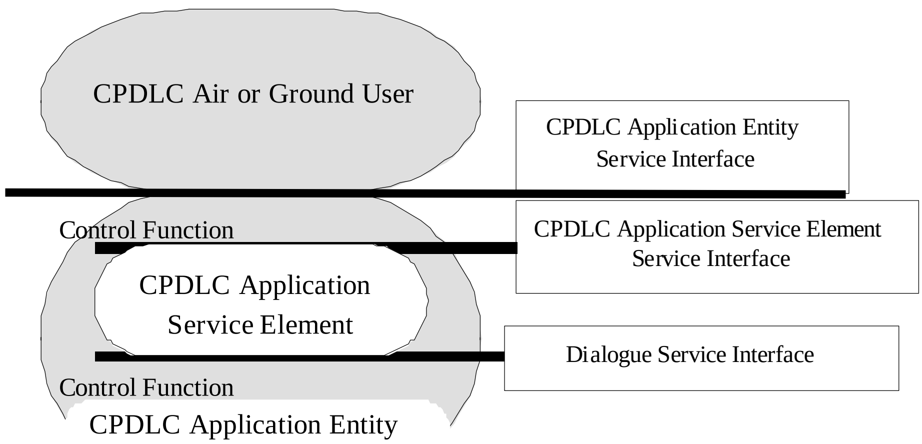

Figure 15: CPDLC Functional model

Services

The CPDLC-ASE abstract service consists of the following services:

a) CPDLC-start service: This service is used by the CPDLC-air-user or CPDLC-ground-user to establish a CPDLC dialogue. It is a confirmed service.

b) DSC-start service: This service is used to establish a DSC dialogue for the purpose of providing down stream clearances. It is a confirmed service

c) CPDLC-message service: This service can be used for pilot/controller message exchange, once a dialogue is established. It is an unconfirmed service.

d) CPDLC-end service: This service is used by the CPDLC-ground-user to end a CPDLC dialogue with a CPDLC-air-user. It is a confirmed service

e) DSC-end service: This service is used by the DSC-air-user to end a DSC dialogue with a CPDLC-ground-user. It is a confirmed service

f) CPDLC-forward service: This service is used by a CPDLC-ground-user to send a CPDLC message to another CPDLC-ground-user. Its primary use is for the forwarding of aircraft requests.

g) CPDLC-user-abort service: This service provides the capability for either the CPDLC-air-user or a CPDLC-ground-user to abort communication with its peer. It can be invoked at any time the user is aware that the CPDLC service is in operation. The CPDLC-user-abort service can be used for operational or technical reasons. It is an unconfirmed service. Messages in transit may be lost during this operation.

h) CPDLC-provider-abort service: This service provides the capability for the CPDLC-service provider to inform its active users that it can no longer provide the CPDLC service. Messages in transit may be lost during this operation.

PROTOCOL

The CPDLC ASE offers a wide range of messages which can be exchanged between the communicating users. These messages correspond to the various exchanges which usually take place between a controller and a pilot.

IMPLEMENTATION

The CPDLC ASE has been implemented as a separate ASE inside the overall PATN software infrastructure. It has been developed by CENA.

- **DOWNLINK OF AIRCRAFT PARAMETERS (DAP) ASE**

OVERVIEW

Currently the aircraft parameters available on the ground are fixed and a rough estimation of the actual aircraft parameters based on the known aircraft type. The PD/3 DAP service is intended to provide supporting information to especially the ground Trajectory Prediction (TP) function. This information is mainly related to preferred settings that the airborne FMS uses in its own trajectory prediction. The parameters will be stored in a data base within the ground ATC system. This data base could serve any user (including adjacent centre) that is interested in the available parameters from the aircraft. From this concept only the ATC centre containing the aircraft in its area of responsibility will communicate with the aircraft. The ground ATC centre should use the information when the aircraft is leaving the area of responsibility of the ATC centre and enters an adjacent ATC centre in order to finish the existing dialogue.

Figure 16: DAP Functional model shows the high-level functional model of the DAP application.

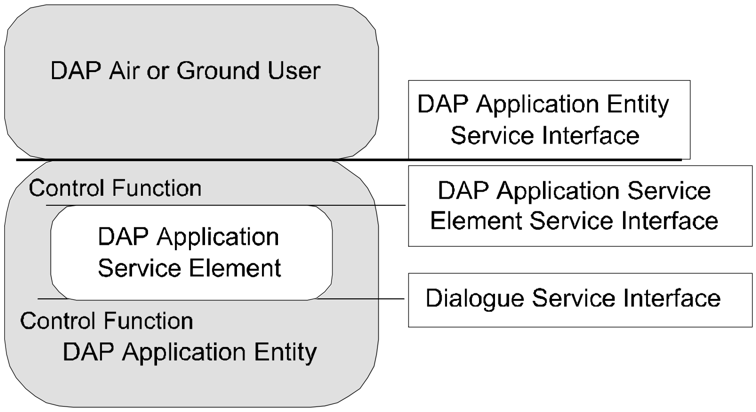

Figure 16: DAP Functional model

<u>SERVICES</u>

Several ground ATC functions may benefit from accurate aircraft parameters available on the ground. These ground ATC functions are:

- Trajectory Predictor (TP) and
- TP dependent processing like Flight Path Monitor (FPM), Conflict Probe (CP) and the Problem Solver (PS);

The main objective of the DAP service is the support of the Trajectory Predictor.

All DAP dialogues are initiated and controlled by the ground user process. There is no DAP user interface required in the aircraft.

The DAP ASE is able to support the following reporting contracts:

a) demand contract: down-link a report only once,

b) event contract: down-link a report when a parameter exceeds a certain threshold value

c) periodic contract: down-link a report every *x* seconds, where *x* is defined by the ground DAP user at contract set-up

d) combined contract: combination of the event and periodic contract

The DAP ASE is responsible for guarding the report generation by the airborne DAP user by means of expiration timers, the message sequences, message contents,

The actual parameters in the DAP report contains the following information:

-aircraft weight,

-mode of flight,

-time

The preferred aircraft parameters in the DAP report contains the following information:

-preferred flight level,

-preferred cruise speed,

-preferred climb speed,

- preferred descent speed

PROTOCOL

The messages exchanged by the DAP ASEs and which define DAP protocol are summarised in the following table:

Message	**Purpose**	**Source/destination**		**Triggering event**	**Message contents**
		from	**to**		
DAP_Contract	Initiating the DAP service and establishing a contract on the response mode and the interval time, or Changing the response mode and/or the interval time, if required (e.g. to prevent network congestion).	ground	air	The ground ATC system will initiate the dialogue upon the aircraft entering its airspace. The ground wants to change the response mode and/or the interval time p.	response mode (*Response-mode*) conditional: interval time (*ReportingInterval*)
DAP_Report	Downlinking of the relevant aircraft parameters.	air	ground	once, time or event driven depending on the required response mode.	actual a/c parameters preferred a/c parameters
DAP_UserAbort	The ground or aircraft system ends the DAP service in a regular way.	ground/ air	air/ ground	The ground or air user wants to close the dialogue.	Reason (*UserAbortReason*)
DAP_Pabort	The provider ends the DAP service in a non-regular way.	PATN	air/ ground	The communication system wants to terminate the dialogue.	Reason (*ProviderAbortReason*)
DAP-Error	The user process is notified of an error in the communication.	PATN	air/ ground	An error occurred in the dialogue.	Reason (*ErrorReason*)

IMPLEMENTATION

The DAP ASE was designed as a separate process, connecting to the external PATN dialogue service interface. It has been developed by NLR.

- **POSITION REPORTING (PR)**

OVERVIEW

For the PD/3 flight trials, the need has been identified for down-linking of position information from the aircraft to the ATC simulator(s). This information has to be down-linked periodically.

Following different local PD/3 requirements, two implementation of the Position reporting have been provided by PATN.

The first one has been based on the development of a specific ASE, the Position Reporting ASE and was designed in order to fulfil NLR PD/3 requirements.

The second one has been based on the use of an already existing ASE, the Controller Pilot Data-Link Communication (CPDLC) ASE.

PROVISION OF POSITION REPORTING SERVICES VIA THE PR ASE:

This solution has been chosen for the NLR PD/3 demonstration and has been used in NLR Amsterdam site and in the NLR Citation II Aircraft.

The functional model of the PR ASE is shown on the following figure:

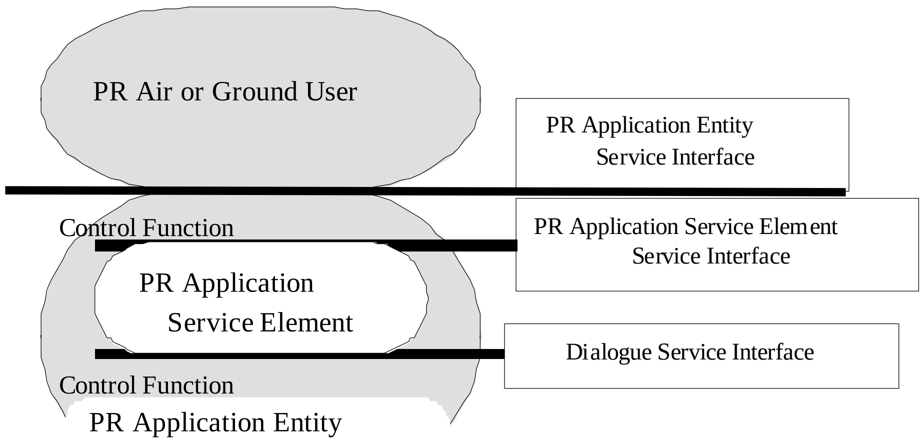

Figure 17: PR Functional model

PROTOCOL

The PR ASE provides with the exchange of the following information:

-time stamp of position information

-position (lat, long, alt)

-airframe-id (24 bit ICAO aircraft identifier)

-air vector (heading, air-speed, vertical speed)

-ground vector (track, air-speed, vertical speed)

The DAP (Down-link of Aircraft Parameters) application does not foresee in the need for position information, however the communication functionality required for this position report is very similar to the DAP dialogues.

Note that, following NLR PD/3 requirements, this application was only required by the real aircraft.

IMPLEMENTATION

The PR ASE was designed as a separate process, connecting to the external PATN dialogue service interface. It has been developed by NLR.

PROVISION OF POSITION REPORTING SERVICES VIE THA USE OF CPDLC ASE:

This solution has been chosen for the CENA PD/3 demonstration and has been used in CENA Athis-Mons and Toulouse sites and in the DERA/NATS BAC 1-11 Aircraft.

The ASE involved in this exchange is CPDLC: no new ASE has been developed for this purpose.

- Protocol

The message used was the CPDLC message 48 (PositionReport). Its formal specification is as follows:

```
PositionReport ::= SEQUENCE {
    positioncurrent              [0]    Position,
    timeatpositioncurrent        [1]    Time,
    level                        [2]    Level,
    fixnext                      [3]    Position          OPTIONAL,
    timeetaatfixnext             [4]    Time              OPTIONAL,
    fixnextplusone               [5]    Position          OPTIONAL,
    timeetaatdestination         [6]    Time              OPTIONAL,
    remainingFuel                [7]    RemainingFuel     OPTIONAL,
    temperature                  [8]    Temperature       OPTIONAL,
    winds                        [9]    Winds             OPTIONAL,
    turbulence                   [10]   Turbulence        OPTIONAL,
    icing                        [11]   Icing             OPTIONAL,
    speed                        [12]   Speed             OPTIONAL,
    speedground                  [13]   SpeedGround       OPTIONAL,
    verticalChange               [14]   VerticalChange    OPTIONAL,
    trackAngle                   [15]   Degrees           OPTIONAL,
    heading                      [16]   Degrees           OPTIONAL,
    distance                     [17]   Distance          OPTIONAL,
    humidity                     [18]   Humidity          OPTIONAL,
    reportedWaypointPosition     [19]   Position          OPTIONAL,
    reportedWaypointTime         [20]   Time              OPTIONAL,
    reportedWaypointLevel        [21]   Level             OPTIONAL
    }
```

It permits the aircraft to transfer the following information to the ground:

- positioncurrent
- timeatpositioncurrent
- level
- speed
- speedground

- verticalChange
- trackAngle
- heading
- reportedWaypointTime

- Implementation

The PR exchange consists in a periodic activation of the CPDLC-Message by the aircraft application (CMS Lite application) in order to transfer the PositionReport message to the ground application.

- **TRAJECTORY NEGOTIATION (TN) ASE**

OVERVIEW

The purpose of the Trajectory Negotiation application is to support the medium term flight planning process by allowing the air and ground to 'negotiate' on the trajectory to be flown by the aircraft. This negotiation is based on a set of messages permitting the aircraft and the ground to exchange preferred trajectory (aircraft to ground) and constraints (ground to aircraft) in an iterative manner, until an agreement on the aircraft trajectory has been reached.

The functional model of the TN ASE is shown on the following figure:

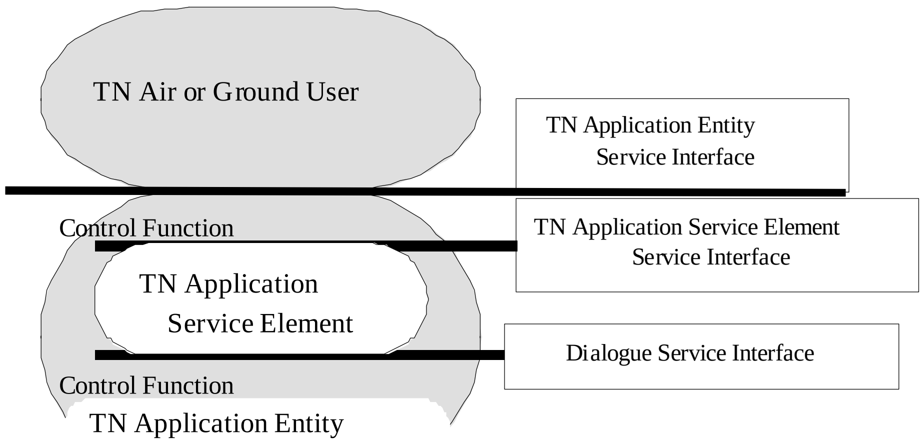

Figure 18: TN Functional model

SERVICES

The services proposed by the TN application are based on five messages exchanges sets:

a) Exchanges involved in air proposal: in which an air application sends a proposed trajectory to the ground user. The ground user can either accept the proposed trajectory, by sending an approval, or ask the aircraft to take into account a list of constraints. The aircraft can then propose a new trajectory to the ground, which, if approved is then activated by the aircraft.

b) Exchanges involved in ground proposal: in which a ground application sends a list of constraints which should be taken into account by the aircraft in defining a trajectory. The aircraft then proposes a new trajectory which can be approved by the ground and activated by the aircraft.

c) Exchanges involved in formalised clearance: issued by the ground and followed by the indication, by the aircraft, of the active trajectory.

d) Exchanges involved in Sector Contract Approval,

e) Exchanges involved in pre-emptive trajectory.

PROTOCOL

The TN protocol used the following messages:

a) ProposedTrajectory, used by the air user in order to specify the new proposed trajectory for the aircraft,

b) ActiveTrajectory, used by the air user in order to specify the negotiated trajectory which will be followed,

c) GroundConstraintList, and FormalisedClearance used by the ground user to specify the aircraft the list of constraints which should be taken into account to calculate a new trajectory,

d) Approval, used by the ground user to specify the aircraft the a trajectory is approved,

e) SectorContract used by the ground user in order to specify a point on the active trajectory where the aircraft has been cleared.

f) Activate used by the air user in order to specify has switched to the active trajectory.

g) Cancel, used either by air or ground users in order to cancel a dialogue in progress.

Note that, following PD/3 requirements, this application was only required by the real and by the simulated (MCS) aircraft.

IMPLEMENTATION

The TN ASE has been implemented as a separate ASE inside the overall PATN software infrastructure. It has been developed by EEC.

Annex B. Satellite Access Subsystems

B-1 MCS AMSS SUBSYSTEM

The MCS 3000 (Figure 19) has the following components:

- Satellite Data Unit (Racal/Honeywell)
- High Power Amplifier (Racal/Honeywell)
- Receive and transmit attenuator
- Cabling

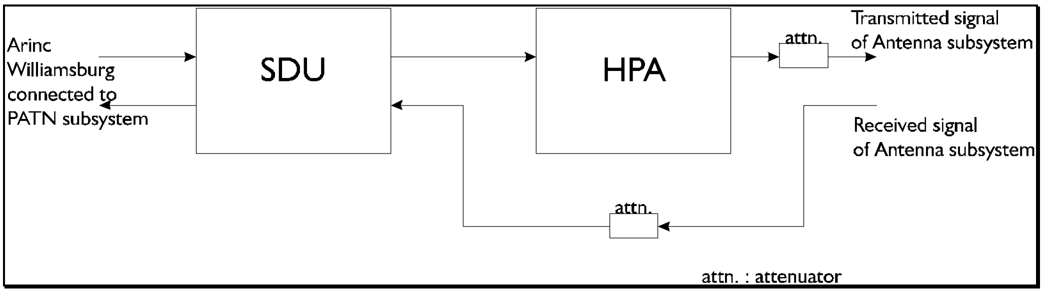

Figure 19:MCS AMSS subsystem

The interfacing between the SUN workstation and the SDU is realised with the converter box. (see section B-3)

B-2 ANTENNA SUBSYSTEM

The antenna subsystem contains a Diplexer/Low Noise Amplifier (DLNA) and a Low / High Gain Antenna (LGA / HGA) manufactured by TOYOCOM.

Figure 20 shows the antenna subsystem

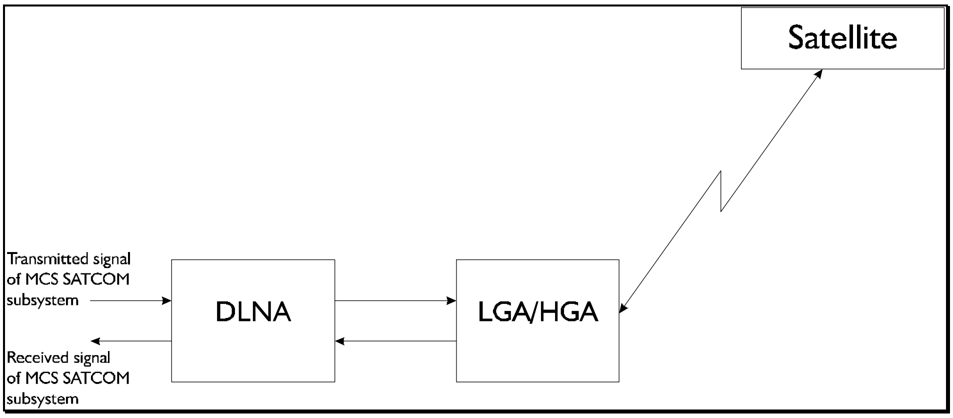

Figure 20: antenna subsystem

B-3 ARINC WILLIAMSBURG/HDLC CONVERTER

The interface between the DATA-3 SDU and the PATN SUN is realised by the CLAW (Converter LAP-B / ARINC Williamsburg) The PATN subsystem requires a RS232-c (synchronous) serial interface (physical layer 1), while the MCS AMSS subsystem which has an ARINC 429 serial interface (see Figure 21). This poses a interfacing conflict between the PATN subsystem and the MCS AMSS subsystem. In addition, the

SUN workstation has a data link layer (layer 2) with HDLC which differs from the MCS AMSS subsystem data link layer: ARINC Williamsburg.

In order to fix these incompatibilities, a converter has been developed which converts the data-flow between RS232/HDLC and the ARINC/Williamsburg. The converter also handles the join/leave events which are required by EurATN in order to get the status information on the condition of the air-ground data connection.

The converter has been developed by NLR specially for installation and operation in an aircraft environment, ensuring correct operation under flight conditions. This poses additional constraints on housing, EMI, connectors and power.

The converter has been used by all sites which were using the MCS AMSS Data-3 equipment.

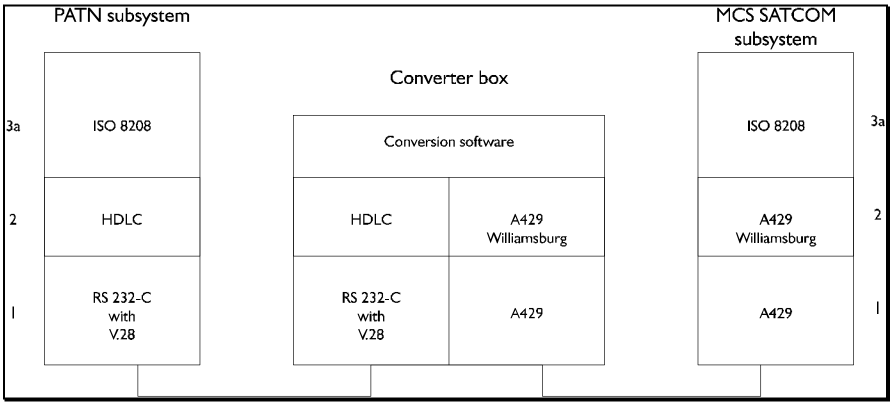

Figure 21: Communication layers of converter box

The converter was based on the following hardware:

- PC board: 386, 25 MHz, PC/104, 4MB RAM
- 2MB Disk on chip
- SVGA port
- PC/104 power supply: 28 VDC
- Sangoma LAPB ISA board synchronous RS232
- TechSAT ARINC IP module

External connectors: RS232 sync, ARINC (in & out) power 28VDC, maintenance: SVGA, keyboard, RS232 async.

Five converters were developed and distributed over the various sites.

B-4 HARDWARE INSTALLATION & VALIDATION

In order to validate the PATN equipment for its correct behaviour in the aircraft environment, a number of tests are required. Some of these tests are required by the provider of satellite communication, and tests are required by the PATN project to prevent problems during PATN flight experiments. [Ref.1]. Results of the test campaign are described in detail in document [Ref.3].

The following tests have been carried out:

1. System Access Approval (SAA)
2. Commissioning (authorisation for use of the MCS AMSS equipment)
3. Verification of functionality of MCS AMSS equipment for use by PATN
4. Functional test with PATN application.

The ‘System Access Approval’ is an acceptation test of the MCS AMSS hardware in the aircraft. This ensures the operation of the hardware without chance of disturbance of satellite or equipment.

The commissioning test followed after the access approval. Commissioning implies the authorisation of Inmarsat to use the satellite space segment with the MCS AMSS equipment in the aircraft.

The third test ‘Verification of functionality of MCS AMSS equipment for use by PATN’ is required to verify correct operation of each aircraft platform. This test exists of two parts.

1) Verifies the correct configuration of the MCS AMSS equipment for the use by PATN.
2) Verifies the interoperability of the MCS AMSS equipment in combination with the PATN hardware (SUN workstation).

Following these tests, the aircraft systems are accepted for the experiments.

The last test demonstrates the correct behaviour of the PATN aircraft platform in combination with the ground systems.

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Annex C. PATN Workstation description

C-1. MAIN FUNCTIONAL CHARACTERISTICS

- **ACCESS TO SUBNETWORK:**

Prior to PATN deployment, each PATN workstation was to have an access to the networks required by the partner:

- ETHERNET LAN access was required in order to provide interconnection means between BIS/ES and ES.
- X.25 (SITA or TRANSPAC) was required in order to provide interconnection means between PATN entities (ground sites together or with simulated airborne sites).
- AMSS access was required in order to provide interconnection means between PATN entities (airborne and simulated airborne sites with ground sites).

- **NETWORKING CORE PROCESS FUNCTIONALITY:**

Prior to PATN deployment, EurATN software is installed on each PATN workstation in order to provide ATN-Transport and ATN-Network functionality over the required subnetworks.

- **ATN ROUTING FUNCTIONALITY**

Each PATN site (ground or airborne) is required to implement ATN routing functionality, i.e. have a PATN workstation configured as BIS/ES or BIS only.

- **ATN APPLICATIONS**

This addresses the ATN application layer and DLG and required applications (CPDLC, TN, DAP or PR). The structure of the Application layer in PATN conformed to the ATN SARPs and is described further in this document. Although identical for each partner, differences appeared in the implementation of various ASEs according to local PD/3 needs.

C-2. HARDWARE AND VENDOR BASIC SOFTWARE

- **ATN WORKSTATION**

Nominal PATN workstation were based on SUN IPX machines. This choice led some partners to some difficulties, as the product was not anymore distributed by SUN Microsystems and not maintained. This is mainly why some differences appeared in the actually used workstation. The porting of PATN on these platform did not lead to real difficulties. The memory requirements for these workstations were of a separate system disk, 200 Mega-bytes hard disk for PATN software and 64 Mega-bytes RAM.

- **OPERATING SYSTEM**

As for workstation hardware architecture, the basic needs were SUN OS 4.1.3 associated with the SUN Patch ID#100173-10 and some kernel specificity described in PATN deployment plan. Both hardware and software requirements were prescribed by PATN lower layers software (EurATN), while PATN upper layers could be (and has been) ported on different platforms (SUN SOLARIS, for CENA PD/3 demonstration and, later, DEC ALPHA for subsequent CENA experiments).

- **ENVIRONMENT**

Required user interface was bourne shell (/bin/sh) and C-shell (/bin/csh), used for administering the PATN stack associated with Motif 1.2 (X11R5) or, Optionally Openwin.

- **X25 INTERFACE**

In order to access its various subnetworks, PATN required SUNLINK X25 7.0 associated to the SUN Patch ID#100328-21.

- **DEVELOPMENT TOOLS**

As PATN was delivered under source format, its generation required GNU C gcc-2.5.7 or higher compiler.