

Anatomy of a CNS/ATM System

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14 March, 2002

Introduction

A reference architecture for CNS/ATM systems is a necessary precondition for establishing common vocabulary and promoting standards in the domain. There have been important attempts to establish such a reference architecture, notably EATCHIP/EATMP efforts of Eurocontrol. Invaluable as they are, these attempts never provided this author with a feeling of completeness. This paper is author's humble attempt to put **the complete** CNS/ATM functionality into an organised structure.

The structure is made as similar to EATCHIP/EATMP as possible.

The Anatomy

The totality of all CNS/ATM functions can be divided into two broad categories, each recognising a different timeline:

- **Operational Functions** are elements of the system, which directly contribute to provision of ATC services. Operational time is the time dimension in which aircraft depart, progress along the air-routes and arrive.
- **Support Functions** are all other elements of the system. Support time is at a much larger scale than the operational time and evolution of the system becomes visible.

The relationship between these two categories is much like the relationship between *the evolution of a species* and the *life of one individual*. In between these two views, the granularity of time is so different that, what appears to be constant in one, suddenly becomes subject to change in the other. Furthermore, the heuristic jump between these two views is so big that mapping phenomena between them is virtually impossible. (Reader is warned that metaphors are seldom complete and must always be taken with a grain of salt.)

Operational Functions

The classification of the operational functions is a reflection of the real ATC world. The real world of ATC is the airspace above the surface of the earth and the conflicting needs of the various users of this resource. The time flows along the lifeline of an individual, e.g. flight, from departure to arrival. This perspective gives birth to the following classification:

- **Environment**
 - **Natural Environment** provides the background canvas for all other entities. It is further decomposed into:
 - **Geography, i.e.** terrain, maps, etc.
 - **Meteorology, i.e. wind/temperature forecasts and Wx products.**
 - **Aeronautical Infrastructure** is a collection of man made artefacts, inserted into the natural environment to help the users exploit the airspace: NAVAIDs, airports, runways, airways, etc. Usually referred to as AeroNautical Services (ANS).
 - **Aircraft Performance** provides insight into the properties of various types and kinds of aircraft vehicles.
 - **Airspace Manager** is a reflection of the real-world division of responsibility between various ATC providers (FIR, AOR, Sectorization, etc.) as well as a reflection of the rules that have been established for using various elements of the airspace (i.e. controlled, uncontrolled, special use, etc.)
- **Surveillance Cluster** provides integration of information about the real world, as observed through sensors.
 - **Air surveillance (radar and ADS/B)**
 - **Ground surveillance (ground radar)**
- **Flight** models the past, present and future of a flight based on flight plan, clearance and surveillance data.
- **ATC Cluster incorporates tools supporting ATC operations**
 - **Flight Management Tools**, a collection of intelligent agents, where each agent services the needs of an individual flight: progress agent, SUA penetration agent, conformance monitoring agent, jurisdiction monitoring agent, etc.
 - **Air Traffic Management (ATM) tools** use insight into several (sometimes all) users of the airspace to help in detecting and resolving their conflicting usage needs.

Support Functions

For a CNS/ATM system itself to exist, we need to perform certain tasks: design the software, prepare the adaptation data, deploy the software and the data on the hardware, start it up and later switch-over or start-over, train the staff in using the CNS/ATM system, collect recording data (display and voice recording in particular), etc. The time flows along the evolution of the system and its ingredients: hardware, software, data, people, etc. This point of view gives birth to the following taxonomy, in chronological order:

- **Hardware/Software** – support for all things hard and soft: production, certification, distribution, problem tracking and resolution, etc.
- **Adaptation** – support to import adaptation data available from commercial providers, create, modify and delete entities in the database, qualify the database for on-line use, etc.
- **Training** (and test-ware) – a means to first test the system in near-real environment and then to train the staff in using the system.
- **Exploitation (SM&C)** – often called *system monitoring and control*, supports: software and data deployment and cut-over, system start-up, start-over, switch-over, capacity and performance data collection and monitoring, on-line adjustment of various parameters and functions, etc.
- **Recording and Playback** – support for display and voice recording, display and voice playback, other data recording and reduction, etc.
- **Floor Configuration Management** - provides support for operator roles, positions, authorisation, etc. as well as a means to (de)consolidate ATC sectors and supervision sub-units.

The time granularity along these categories approaches the time granularity of the operational functions. Nevertheless, the time *as a quality* remains unrelated to flying an aircraft and this makes, e.g. recording and playback, qualify as a support function. The last category, *Floor Configuration Management*, could even be possible to categorise as Operational Service.

Facets

Each entity of a CNS/ATM system, be it operational or support, in addition to the functionality itself, has two distinct facets:

- **CHI** – a means for human operators to interact with the subject CNS/ATM element. Everything, from building the software to resolving a conflict, has a CHI aspect to it. It is important to note that CHI, unlike the software components implementing the functionality, has an integrating property. The more software components are independent, e.g. the aeronautical environment and flight, the better. On the other hand, both the aeronautical environment and flight are integrated in the situation display CHI.
- **Interoperability** – horizontal integration of the CNS/ATM element across ATS units making their boundaries seamless. A special use airspace (SUA), close to the boundary of two ATS units, are of interest to both units. Current data about a flight are of interest to the downstream ATS units along its route. Etc. Similar to CHI, but to a lesser degree, interoperability exhibits integrating forces. E.g. ANS interoperability and flight interoperability often integrate along the same communication path and protocol.

Both CHI and Interoperability domains have their own internal design elements, which provide cohesion to the look and feel of the system.

Colour blending from blue (support) to yellow (operational) is an attempt to visualise their blending into a single system.

ATM System

Support Functions

Software

- ◆ production ◆ certification ◆ distribution ◆ problem tracking and resolution

Adaptation

- ◆ commercial data import ◆ data management ◆ data qualification

Exploitation (SMC)

- ◆ software and data deployment ◆ cut-over ◆ start-up, start-over, switch-over, shutdown ◆ I/F mgmt ◆ time mgmt ◆ fault mgmt ◆ capacity and performance data collection and

Training

- ◆ scenario preparation ◆ preview ◆ execution control (start, fwd, rwd, pause, stop, re-start) ◆ pilot, external I/F, controller and radar simulation

Recording and Playback

- ◆ display recording and playback ◆ voice recording and playback ◆ data recording and reduction

Operational Functions

ATC Cluster

ATM Tools

- ◆ flow ◆ departure and arrival mgmt ◆ medium term and short term conflict prediction ◆ conflict detection ◆ ALTRV ◆ surveillance correlation

Flight Management Tools

- ◆ repetitive flight plans ◆ home base data ◆ SSR code mgmt ◆ progress ◆ conformance ◆ jurisdiction ◆ MSAW ◆ SUA penetration ◆ DAP manager ◆ etc.

Flight Manager

- ◆ flight plan ◆ clearance ◆ trajectory profile

Surveillance Cluster

- ◆ radar data input ◆ plot filtering ◆ tracking ◆ radar weather ◆ DT quality control ◆ ADS/B

Environment Manager

Airspace management

- ◆ FIR ◆ tower AOR ◆ Sectorization ◆ controlled airspace ◆ uncontrolled airspace ◆ special use ◆ etc.

Aircraft Model

- ◆ aircraft types

Aeronautical infrastructure

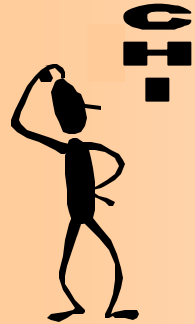
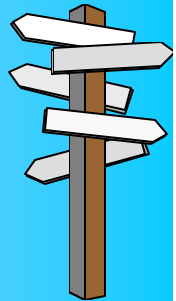
- ◆ airports ◆ runways ◆ fixes ◆ ATS routes ◆ MTT ◆ ocean tracks

Natural environment

Floor Configuration Manager

- ◆ roles ◆ positions ◆ sector (de)consolidation ◆ tower reconfiguration ◆ supervisor (sub-unit) reconfiguration

Interoperability



CHI component is not presented as a component with a boundary, to indicate the effects of integrating pressures. E.g. Environment, surveillance, flight and ATC tools CHI is deemed better when

Floor Management, more than any other component, spans Operational and Support functions.

Interoperability, similar to CHI, exhibits integrating effects.