AEROMACS AIRBORNE ARCHITECTURE OPTIONS
V1.0

Introduction
This paper summarizes the outcome of the discussions within the AeroMACS SESAR P9.16 and P15.2.7 projects and the EUROCAE WG-82 group. It provides a list of potential airborne AeroMACS system architectures that have been already identified and are proposed for further consideration and discussion in the AEEC SAI group, in the context of the AEEC work for the AeroMACS APIM.

Note: The eventual airborne AeroMACS system architecture is expected to be developed by AEEC as part of the AeroMACS avionics standard.

In order to identify the options for the airborne AeroMACS system architecture, the available material from SESAR project P9.16 has been used as baseline to develop the proposals shown below, which should be considered as potential ways of implementing AeroMACS onboard allowing for having early benefits from an AeroMACS implementation on one hand and outlining the target architecture, which has to be considered on a long term basis as a final step, on the other hand.

The following explanations are based on material described in SESAR Project 9.16 document entitled AeroMACS Airborne System Requirements and Architecture Dossier (SRAD) and discussions in the EUROCAE WG82 group for the development of the AeroMACS MASPS (expected to be available by end of year) and in the projects P15.2.7 and P9.16.

Note: Most of the information in this paper is also part of the draft AeroMACS MASPS and is expected to be also included in the published MASPS.

ARINC-664 has defined a formalized organization of the aircraft systems and airborne networks into so-called “aircraft domains”. Aircraft domains are served by airborne networks and systems with the same requirements for performance, safety and security. In ARINC664P1-1 and ARINC664P5, it is suggested to group the aircraft computing network into four aircraft domains – the Aircraft Control Domain (ACD), the Airline Information Services Domain (AISD), the Passenger Information and Entertainment Services Domain (PIESD), and the Passenger Owned Devices Domain (PODD):

- The **Aircraft Control Domain** comprises the systems which control the aircraft from the flight deck and the systems for environmental control, smoke detection and slides and doors management.
- The **Airline Information Services Domain** provides operational and airline administrative information to the flight deck and the cabin and maintenance services and to support the passengers.
- The **Passenger Information and Entertainment Services Domain** provides the in-flight entertainment (i.e., video, audio, gaming), passenger flight information, and access to the Intranet and Internet using built-in terminals including related services like Voice over IP, Short Message Service (SMS), and Email.
- The **Passenger Owned Devices Domain** is a network of those devices that passengers may bring on board to connect to the passenger information and entertainment services or to one another.

To ensure the appropriate level of safety and security, these domains are physically separated by appropriate means. Notably, aircraft control systems are separated from other domains. This strong partitioning results in the introduction of constraints and restrictions for the use of the communication systems by the different airborne data link applications. Typically:

- Radio communication equipment attached to the ACD are today only accessible to data link applications (typically ATC/AOC) located in the ACD,
- Radio communication equipment attached to the other domains are mainly for applications (typically AOC/AAC/APC) located in these domains. ACD applications have very limited access to these communication means (typically, they can be used in the Air-to-ground direction only.
by ACD applications),

Note: The Satellite Data Unit (SDU) is currently an exception to the above typical repartition. The SDU is currently shared between and simultaneously attached to the ACD and the other domains. However, this is tolerated through the application of very strict security requirements and security assurance processes on the equipment, notably for what relates to the segregation of the data flux and to the demonstration that the equipment cannot be used as a backdoor gateway in between the domains.

It is important to note that the types of applications that are to the use AeroMACS radio equipment operating the protected (ITU) AM(R)S band are limited to the ones linked to the safety of life (ATC) and regularity of flight (AOC). This implies that applications in the PIED and PODD domains are not candidates to be supported by AeroMACS and the use of AeroMACS is only relevant to the ACD and AISD domains.

However, if due to security restrictions, only ACD applications are enabled by AeroMACS radio, the business case for this technology is impacted. In the absence of an implementation mandate, it will be the airlines that may push for the equipage of aircraft with AeroMACS, provided that there is a positive business case (benefits of the services enabled exceed the costs of installation and support). Operational services such as EFB, administrative, maintenance and flight support, may be left out and, without them, a great part of the potential to support regularity of flight applications (AOC) is removed. Currently a key improvement that aircraft operators expect from a new data link is to enable reduction of turnaround times, holding times (at the gate or in taxi), and simplified administrative operations. In this scenario though, AeroMACS will not be perceived as a solution to aircraft operator problems of turn-around time or in-gate maintenance operations.

If, on the other hand, only AISD applications are enabled by AeroMACS, safety-critical flight control services such as ATC clearances, OOOI, SIGMET will be left out and these are services that are likely to be of interest to ANSPs. Considering the current issues being investigated for the current data link, there is an interest for AeroMACS to be able to support ATC services especially with the introduction of the new concepts in SESAR and NextGEN.

Assumptions regarding the initial Implementation of Airborne AeroMACS systems

It is expected that the first implementations of AeroMACS systems in Airports and on aircraft could start from 2016 onwards.

AeroMACS is the first ATN/IPS-compatible “Future Communication System” that is candidate for installation on aircraft. Hence, implementation of the AeroMACS in the Aircraft Control Domain (ACD) would need to be coordinated and come concurrently with other relevant evolutions, such as:

1. An ATN/IPS router will need to be concurrently developed and certified,
2. Security issues pertaining to the interconnection of the ACD with external IP networks will have to be addressed. This may necessitate the development of specific security systems (e.g. firewall/proxy applications),
3. Adaptations at the level of the Airborne ATC applications and/or of the ACARS/ATN router will be needed to allow ATC communications though the AeroMACS.
4. Adaptations at the level of current AOC applications in the ACD will be needed to allow air/ground communications of these application though AeroMACS,
5. Cockpit HMI (Radio Management Panels, Flight Warning) and transverse functions (Central Maintenance System, Configuration Control Systems, ..) will be impacted.

Given the significant amount of developments that might then be necessary, the introduction of the AeroMACS technology as a first ATN/IPS–compatible communication system in the ACD could be very challenging from a technical and business case standpoint. Based on this consideration, this paper identifies six scenarios covering near-term to mid and long-term perspectives as well as support for different services.

The various scenarios are detailed below.
Scenarios

Scenario 1-A – “Near term Initial installation of the AeroMACS MS in the AISD domain”:

Scenario 1-A assumes that with a near term perspective, an AeroMACS MS (Mobile Station) could be initially introduced as an additional communication media of the AISD domain, attached to the existing AISD “Open IP” router, as a complement or alternative technology to the current or coming gatelink technologies (WIFI/ GSM/GPRS/EDGE/UMTS/LTE/WIMAX...). Following this scenario, the AeroMACS system could be implemented as a standalone equipment similar to current TWLU equipment, or could be integrated (added) within the current gatelink communication equipment.

Scenario 1-B – “Near-medium term Initial installation of the AeroMACS MS in the ACD domain”

Scenario 1-B assumes, in the short-medium term, the availability of an AeroMACS MS connected to the AISD domain but designed and pre-installed to be hosted in the ACD Domain in preparation of the longer term scenario 3A/B described farther below. In terms of initial capabilities and supported services this AeroMACS MS is the same as the one shown in Scenario 1-A. The difference with Scenario 1-A is that a Scenario 1-B AeroMACS equipment would be designed and possibly pre-installed to be directly interfaced with the ACD airborne network and with peripheral ACD avionics systems. In particular, a Scenario 1-B AeroMACS equipment could be designed with the physical Inputs/Outputs modules (e.g. ARINC 429, AFDX, ...) necessary to interface with the ACD systems generally involved in the monitoring, control, and maintenance of ACD radio communication systems (e.g. to support possible interfaces with an ACD Radio Management Panel (RMP) or Multi Purpose Display Unit (MCDU), with the Failure Warning Computer (FWC), with the Aircraft Centralized Maintenance System (CMS), and Data Loading and Configuration System, etc...). The equipment would also be designed with provisions to support an interface with the future ATN/IPS router envisioned to be installed in the ACD at a longer term.
Scenario 2-A – “medium term Initial installation of the AeroMACS MS in the ACD domain”:

Scenario 2-A assumes that with a Medium Term perspective, the AeroMACS equipment could be initially developed and certified as a more global equipment, providing in the same “box” the following capabilities: 1) the AeroMACS MS (Mobile Station) functions, 2) an initial IP router function, 3) a (optional) security function at IP Level, 4) a function allowing the encapsulation of ACARS messages over IP (and AeroMACS) and 5) a function allowing the encapsulation of ATN/OSI messages over IP (and AeroMACS).

AeroMACS System Security assures secure Air to Ground and Ground to Air MS-BS (Base Station) communications, implementing authentication (PKMv2), data encryption (AES) and integrity check. On top of this AeroMACS security framework the AeroMACS “Box” can optionally implement a security capability at IP level (e.g. IPSEC) to improve privacy and integrity of communications. An (optional) Firewall capability, to improve segregation of the ACD domain from the outside IP world, can be also added.
Scenario 2-B – “medium term installation of the AeroMACS MS in both the ACD and AISD domains”

In the medium term, the AeroMACS “Box” onboard could simultaneously be connected to the ACD and the AISD Domains, thanks to its capability to guarantee the needed segregation among ACD and AISD users. This approach is very similar to solutions currently envisaged for easing introduction of/transition to new IP-based satellite communication services in the ACD (Iridium and Immarsat-SBB).
Being AeroMACS a native-IP system, it would be connected directly to the AISD OpenIP Router. Instead, the connectivity with the ACD COTS ACARS+ATN Router depicted in Figure 4 would be guaranteed by an appropriate SubNetwork Dependent Convergence Function Layer. A similar solution has been already tested and validated under the SANDRA Project, allowing interoperability between AeroMACS MSs and COTS ATN/OSI Routers (See Figure 5).

A security capability, on top AeroMACS security framework, should be implemented at IP level. The AeroMACS “Box” security capabilities should encompass:

- Data Authentication, Cyphering and Integrity check functions, to improve privacy and integrity of data.
- A Firewall function to segregate the ACD from the AiSD domain, avoiding the Open IP world to access to the ACD Domain

It has to be noted that the needed Security Requirements to be guaranteed by this Scenario increase the complexity of the AeroMACS MS, providing however the advantage of having a single AeroMACS MS connecting both ACD and AISD Users.

![Figure 4: AeroMACS system integration on A/C – Scenario 2-B](image)

**Scenario 3-A – “Longer term installation of the AeroMACS MS in the ACD domain”**

Scenario 3-A assumes that in a longer term, when Aircraft will be equipped with ATN/IPS router in the ACD domain, the AeroMACS MS will be developed as a certified radio-communication system of the ACD domain, attached to the ATN/IPS router.
Scenario 3-B – “Longer term installation of the AeroMACS MS in in both the ACD and AISD domains”

Scenario 3-B assumes that in a longer term, when Aircraft will be equipped with ATN/IPS router in the ACD domain, the AeroMACS MS will be developed as a certified (lev. D) radio-communication system of the ACD domain, attached to both the ATN/IPS router and the AISD “Open IP” router. The needed segregation between ACD and AISD users will be granted by the AeroMACS system and by IP level security capabilities (as explained in the scenario 2-B) implemented between the ATN/IPS (referred to also as AeroIP) and OpenIP routers (outside the AeroMACS MS onboard system) (See Figure 6: AeroMACS system integration on A/C – Scenario 3-A)
The above scenarios define different strategies for implementing an AeroMACS System on aircraft, which may lead to the definition of different airborne AeroMACS System architectures.

It is worth underlying that possible combinations of the above Scenarios could also be envisaged. For instance, the possibility to implement both Scenarios 1-A and 3-A, in the Long Term should not be precluded. This scenario could allow using 2 separated AeroMACS MS devices onboard, using a single antenna thanks to an appropriate branching system. This solution would grant a physical segregation between ACD and AISD domains. See Figure 9.
AeroMACS Airborne Architecture: Potential Options

Figure 9: Physical Segregation between ACD and AISD

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Conclusions – Way ahead

This paper summarises some considerations for the AeroMACS airborne architecture and identifies some potential options for the integration of AeroMACS on board the aircraft. Additional options may exist and should be further considered if they provide advantages and benefits.

It is expected that the AEDEC will progress the task to identify the best architecture options that will support the Airline and User in general needs in order for AeroMACS to provide appropriate support to the various services.