INVITED PAPER

# MISSION AVIONICS SYSTEMS IN A MILITARY AND CIVIL ENVIRONMENT

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## Abstract

*This paper describes an avionics architecture suitable to combine military avionics needs with requirements of a civil environment. In past decades systems where designed for operation in a military environment with less or no interface to systems outside this scenario.Civil avionics were set up in the same way as federated systems comprising dedicated LRUs, each covering a well-segregated function. However, in the past decade more and more functionality was added to civil aircraft, including functions with contributions from more than one system. Thus data exchange requirements increased. At the same time advances in computer processing capability, software technology and network technology paved the way for Integrated Modular Avionics (IMA) approaches built around advanced interface networks, e.g. ARINC 664.Driven by cost as well as by functionality, the decision was made for the European Military Transport Aircraft A400M to define a basic vehicle avionics concept supporting all operations in a civil environment derived from state of the art commercial avionics lay outs from air transportation platforms, complemented by system packages to perform the military tasks. Consequently civil certification standards and procedures were applied and a so-called "basic aircraft" will receive a civil type certificate from EASA.*

*The paper describes several options to complement a civil avionics architecture with military functions.*

## Introduction

For the development of new military airborne systems the use of commercial trends and technologies is increasing. This approach is especially visible in military aircraft that are either a derivative of a civilian basis or fly quasi-civilian missions. A good example is the European Military Transport Aircraft A400M. In addition to the basic vehicle avionics being a derivative from A380 system the required military functionalities and systems can be found in a mission avionics package, communicating with the platform systems via appropriate gateways.

The design of functional modules and computers on this platform for both the basic vehicle and mission avionics introduce an open and modular SW architecture and ensures the required robustness against obsolescence. Partitioning of SW with different level of criticality enables the integration of various applications on this modern computer platforms.

Along with this concept comes the ability to integrate and exchange SW modules with comparatively modest effort to introduce new capabilities responding to new operational or regulatory requirements. Off course, appropriate qualification and certification processes have to be applied.

The operator finally gets a system that allows future upgrades and adaptation to new mission needs in a much more flexible way than it is the case for today's fragmented avionics.

## Civil / Military Avionics Architectures

The avionics architectures introduced for the A400M have their roots in previous military and civil avionics architectures.

In past decades the avionics system design for military platforms was focused on pure military functionality, compactness and robust integration as well as military qualification. Systems where designed for operation in a military environment with less or no interface to systems outside this scenario. In all these military avionics systems so called federated systems consisting of dedicated LRU's for the different functionalities onboard like Flight Control Systems, Flight Management Systems, Communication, Navigation, Surveillance and the military functions where used based on avionics architectures from the 60's and 70's. However, with the requirement for ever increasing functionality and performance complexity of the systems increased. At the same time adapting to changing operational requirements became more and more difficult. And finally the military budgets in general could not cope any longer with the sky-rising cost of this approach.

Civil avionics architectures departed from the same roots as their military counterparts. They also were set up as federated systems comprising dedicated LRUs, each covering a well-segregated function. Due to the almost one-on-one allocation of functionalities to LRUs data exchange requirements could be managed by point-to-point connections not mandating bus-type interface systems. However, in the past decade more and more functionality was added for civil aircraft, too, including functions with contributions from more than one system. Thus data exchange requirements increased. At the same time advances in computer processing capability, software technology and network technology paved the way for Integrated Modular Avionics (IMA) approaches built around advanced interface networks, e.g. ARINC 664. Besides the increased performance those architectures promised reduced cost through standardization and increased flexibility.

Driven by cost pressure to procure and maintain the airborne systems the military world was opened stepwise to allow the usage of civil avionics components under certain conditions. This development reached a peak with the avionics approach of the European Military Transport Aircraft A400M. Driven by cost as well as by functionality, the decision was made to define a basic vehicle avionics concept supporting all operations in a civil environment derived from state of the art commercial avionics lay outs from air transportation platforms, complemented by system packages to perform the military tasks (Fig.1).

Consequently civil certification standards and procedures were applied and a so called "basic aircraft" will receive a civil type certificate from EASA. On top of benefitting from the state-of-the-art civil technology and the cost advantages this enables this military aircraft not only to operate in national airspace but to participate in commercial air traffic under given civil regulations without prior permission from neighbor states, when entering their airspace.

## Military Functions in Civil Avionic Systems

If a civil avionics architecture shall be complemented with military functions several options exist.

With the technology level reached with IMA one option could be that next generation of platforms could have a common IMA architecture for both basic vehicle and mission avionics. But this bears a threat that those solutions will be proprietary from avionics supplier to avionics supplier and the adaptation of the mission package can only be done by these suppliers having full control over the entire avionics.

An alternative could be seen in coming back to the "old fashion" federated structure having not boxes for each and every function but using two avionics sections, the basic vehicle avionics on the one side and the mission avionics on the other side, both based on IMA but with well defined interfaces and task allocation (Fig.2). This enables the mission package being more or less independent from the supplier of the basic vehicle avionics and offers more flexibility in system adaptation and modification.

Another advantage can be seen in the possibility to use different communication networks in both sections sometimes driven by the need to use legacy military equipment communicating via MIL 1553 while the basic vehicle avionics is using ARINC 664 already.

Finally this type of segregation promises advantages in the certification process as will be laid out in the following chapter.

## Mission Avionics Layout Considering Civil Certification Aspects

Avionics development is driven by increasing system functionality, performance and cost. Certification represents a significant part of the overall cost chain. Having in mind that military airborne systems will be operated in a dual environment, certification of military platforms according to civil regulations becomes a new aspect in the development of such systems. Therefore it is quite obvious especially for platforms being operated most of the time in a civil regime, to copy the avionics parts proven and certified already on civil platforms and to extend the functionality by integrating an appropriate mission subsystem, which also meets the given design rules of the civil environment with respect to HW, SW and architecture.

Following that concept the well defined civil design and development environment can be transferred and adapted to the military needs (Fig.3). Civil standards will be used for the HW (RTCA/DO 254) and SW (RTCA/DO 178B/C) design as well as for open IMA architectures (ARINC 653).

Avionics computing in the past was a basic element in each of the avionics functions hosted in a dedicated avionics equipment. Computing power was designed according to the requirements of the individual functions. This concept was sufficient for commercial avionics where functionality is well defined and changes do not occur in short time frame.

Military environment is much more dynamic. Functionality has to be adapted to operational requirements, new mission tasks and threats. Obsolescence is also an issue for military systems causing extensive costs for upgrades and redesigns over the lifecycle. Open and modular concepts increase the independence between S/W and H/W, allowing for greater flexibility with regards to adaptation of systems to military needs The new approach helps to reduce cost and time in military system design, development as well as system upgradeability and maintainability.

However, when combining civil and military parts with the objective to benefit from the certification credit of the civil part it is crucial to clearly segregate the military from the civil part. Otherwise a high risk exists that the integrity of the civil part in front of certification authorities is violated and the certification credit is lost. Here a solution maintaining clear separation between the two "sections" is of advantage.

### System Design/Integration/Validation Chain

For the development of avionics a certain development environment is mandatory for the entire chain from definition of a system until certification. Like big airframe companies define their own development process avionics system companies perform the same approach. The well known V model gives a good guideline to structure the process from definition to validation, certification up to the in service phase of a product or system (Fig.4). Of course, in order to finally obtain a civil certification the development processes must fulfill the process requirements laid out in the relevant development standards, e.g. SAE ARP 4754, RTCA DO 254 or RTCA DO 178B/C.

Based on the customers Concept of Operations (CONOPS) today OEM's intent to integrate first teier suppliers at an early point in time into the system definition and system design process to ensure a continuous concept flow down from system to equipment and components on the one hand and to harmonize the integration of the equipment and subsystems into the system towards qualification and certification of the entire system.

The early involvement of sub-system supplier bears the advantage to harmonize all the sub-system solutions at a very early point in time and to reduce development risks. Starting with the architecture, the system network, the communication needs between the sub-systems, and the allocation of functions can be worked out in a holistic approach. This helps to identify functional and communication bottle necks earliest. Having that picture the subsystem requirements definition and design is much easier and the complexity of interaction of all the subsystems is more transparent. Finally the early involvement of the specific expertise of the suppliers significantly reduces the risk of imposing difficult to fulfill requirements to a subsystem or equipment.

This cooperative approach starts with the common understanding of the basic operational needs. Derived from that the mission needs and their influence to the entire system as well as to the avionics layout can be investigated. Certification aspects are reflected in that phase of the design as well as the sub-system and equipment design assurance level required for the functionality. In this phase of the development the principle architecture aspects will be fixed and the allocation of functionality has to be investigated carefully with the involvement of all relevant stakeholders. In some cases the simulation of the data exchange between the different elements of the avionics can help to minimize integration risks and to identify critical interfaces with respect to priority, latency, and load.

In this phase of the development also life cycle cost aspects (LCC) have to be addressed. A study of the Defence Acquisition University indicates that as early as at the end of the concept phase 70% of the life-cycle-cost is committed (Fig.5). This means that suboptimal decisions taken in the concept phase w.r.t. life-cycle-cost are very difficult to recover in earlier phases.

So during these early phases of the development a major task is to find the right balance between development cost, flexibility of the system to cope with a changing requirements environment over the life cycle and the cost of ownership, considering that systems like mission and transport aircraft typically are planned for an operation period of 30 years and more. The Life Cycle Cost can be considered in two categories namely:

**Non Recurring Costs** (independent from the produced quantities)

- Design, Development, Certification and Productionisation/Industrialisation.

The NRC for design, development and certification/qualification is influenced by the following parameters:

- Final configuration of the aircraft such as general architecture and complexity
- Maturity and availability of the chosen technologies and major sub-systems
- Certification/Qualification standards Customer specification and number of variants
- Final configuration of the mission equipment (mission avionics, survivability systems, Day/Night All Environment technologies)
- Number of partners and industrial program structure
- Overall program governance.

**Recurring Costs** (as unit costs multipliable for the produced quantities)

- Production Unit Cost
- In-service Operating and Support Cost
- Modifications and upgrades

It is anticipated that the basic unit cost will vary with the final sizing/weight of aircraft required to satisfy the mission profiles.

Besides that cost occur for the provision and operation of a support infrastructure starting from development and set-up of training means though maintenance facilities to finally development and provision of mission planning and maintenance management systems. Moreover before introduction of a new system into the inventory personnell has to be trained and procedures have to be developed. Depending on the novelty and complexity of the new system this can take significant effort.

For the in-service operating cost it is assumed that a mission aircraft will operate for 300 hours per year for 30 years. The in-service operation and support cost includes spares, repair and overhaul and maintenance and is estimated to be approximately equal to 130% of the unit cost. This estimate excludes the cost of fuel, aircrew, training and the establishment of a training.

It can be also assumed for each aircraft that during its life it will undergo upgrading and modernization at a rate in line with historical records, although the future dynamics in military doctrine during a 30 years period are difficult to forecast and may have a profound impact on such modernization costs. As a rule of thumb cost of modifications, through 30 years, can be estimated to be approximately 1/3rd of the unit cost.

Along the development process deviations in one system caused by technology limitations and their consequences for other sub-systems can be recognized in time and risk, mitigation can be performed in an integrated engineering process. Saying this will not happen in a well defined environment with clear definitions does not mirror the daily experience. A lot of cost is sunk by non harmonization between the sub-system stakeholder and the overall system responsible unit.

## Enabling Technologies

Coming back to the general question of having IMA structures for an avionics system or following federated concepts the question has been answered, what is the benefit of IMA versus mixed or federated solutions and what is the technology needed. The basic concept of IMA is to have common modules with different applications. Both have to be designed to cover a wide spread of functionality. In a pure civil environment there is a certain chance to reach that goal if the applications do not require extreme module layouts.

For military applications it can happen that the processing load is extremely high - real time driven- and distribution of the processing power to several modules is not possible due to e.g. timing requirements. High performing computing modules help to solve such cases following the same rules for open IMA w.r.t. standardized interfaces between HW and applications SW, segregation of different applications on the same computer platform and processing applications with different level of criticality.

## Conclusion

Summarizing the possible architectures it can be seen that pure IMA is a favorite for military avionics solutions where a high integration level comes along with a very compact avionics system design and hard space and weight requirements. On the other side a more common module oriented IMA can be seen in a civil environment, especially where the complexity of applications is limited. In such architectures the transition from IMA to federated concepts depends on the overall complexity of the system, as this is the case for air transport platforms. A special case of IMA can be seen in a mixed civil military concept as the one for the already mentioned Military Transport Aircraft A400M following the logic to use what is state of the art in a commercial environment for the basic avionics and complement this concept with a federated mission package, which can be IMA or IMA like in itself.

To summarize the above the recommendation for Mission Avionics Systems therefore is

- the segregation of basic vehicle, civil and military functionality by using a layered avionics architecture approach to allow dual use and COTS for cost optimization
- to use civil standards to that extend supporting the system certification according to civil rules and regulations to a maximum extend
- to use open architecture concepts for software and hardware to support robustness of the system against obsolescence and to offer a high flexibility in adapting the avionics to upcoming operational needs
- to enable various suppliers to integrate / add functionalities into the avionics system by maximum use of standard hardware/software interfaces.

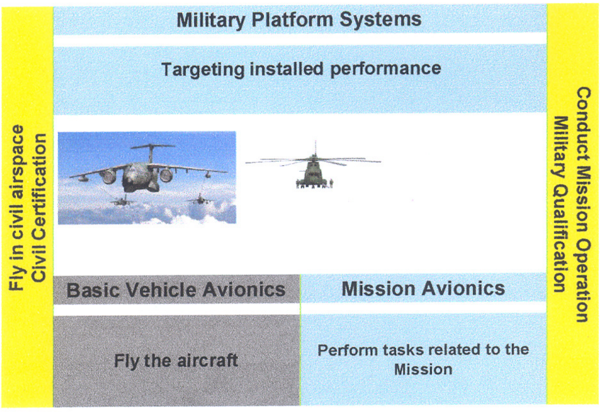

*Fig.1 Basic Vehicle and Mission Avionics Package*

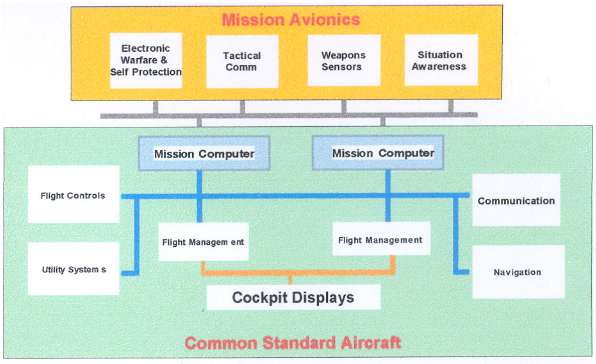

*Fig.2 IMA Based Federated Avionics Architecture*

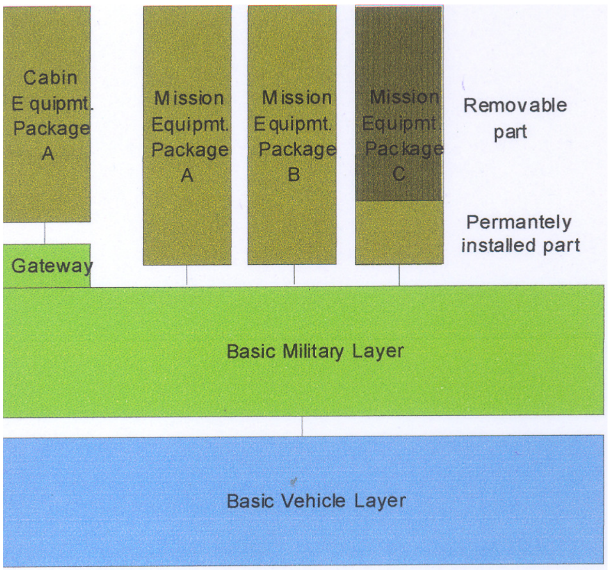

*Fig.3 Layered Avionics Architecture*

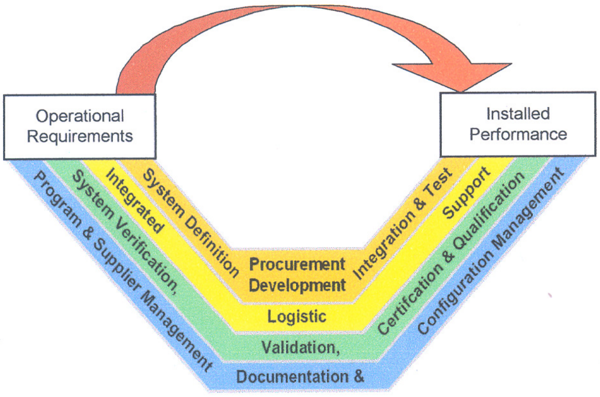

*Fig.4 V Model Development Process*

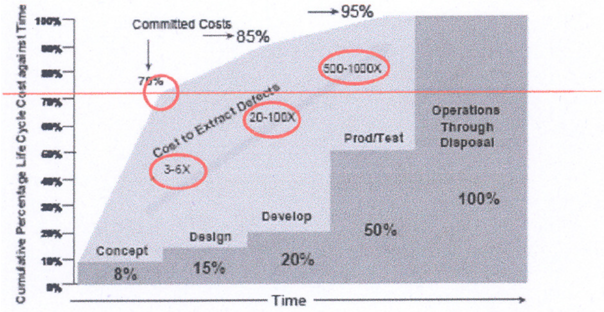

*Fig.5 Occured and Committed Life-Cycle Cost Over Program Life*