Abstract: The objective of this work is to give an overview of the Integrated Modular Avionics (IMA) concept.

Palavras-Chave: IMA, Simulation, Control.

1. INTRODUCTION

The growing demand for services and products with requirements more and more complex, combined with the offer of capacity of communication and computation at costs increasingly smaller, are stimulating industries as space, aeronautics and automotive ones to migrate from distributed federated architectures to integrated architectures.

Based on that, the IMA concept was created. The central ideal of IMA is the sharing of hardware; that is, many applications sharing the same processing unit. Thus, it is possible to reduce the cost with processors, wiring, I/O, etc. Besides that, other critical objectives of the aeronautics and space industries are met, such as reduction of weight, size, energy consumption and cost.

One of the first commercial aircrafts to use IMA technology was the Boeing 777 with its Airplane Information Management System (AIMS).

The AIMS is the brains of the Boeing 777 and it combines primary flight display, navigation display, EICAS display, flight planning, navigation, performance management, airplane and engine monitoring, communications management, digital flight data acquisition, and data conversion gateway functionalities into a single integrated system (Aleksa and Carter, 1997).

Military aircrafts such as the F-22 Raptor, F-35 and Dassault Rafale has also adopted the IMA concept. The Rafale uses a Modular Data Processing Unit (MDPU). This architecture hosts flight management system, data fusion, fire control, man-machine interfaces, etc.

The newest projects from Boeing, the 787 Dreamliner, and from Airbus, the A380, are taking advantage of IMA as well.

Moreover, the two biggest space agencies of the world, National Aeronautics and Space Administration (NASA) and European Space Agency (ESA) are studying the IMA concept.

2. BASIC CONCEPTS

2.1. FEDERATED ARCHITECTURES

Federated Architectures are based on dedicated computational modules or processing units distributed across the vehicle. These modules have different names depending on the world they are inserted. In automotive world they are called Electronic Control Units (ECUs), in aeronautic world Linear Replaceable Units (RLUs) and in space Orbital Replaceable Units (ORUs) (Alena, R.L. et al.). Generally, each module hosts one single application within the avionics system.

The International Space Station (ISS) and the Boeing 767 systems are examples of Federated Architectures. The ISS uses a large number of ORUs and the Boeing 767 a large number of LRUs.

Figure 1 depicts a Federated Architecture where each application has a dedicated module to its tasks.

![Fig. 1 – A Federated Architecture. Source: (COTS Journal)](http://dx.doi.org/10.5540/DINCON.2011.001.1.0071)

2.2. INTEGRATED ARCHITECTURES

In Integrated Architectures, each module hosts numerous applications of different criticality levels (Figure 2); each application is isolated by a robust partitioning mechanism specified by the ARINC 653 standard. This breaks such module into multiple virtual computers, each one hosting an application (Black and Fletcher), see Figure 3.
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2.3. ARINC 653

ARINC standards are prepared by the Airlines Electronics Engineering Committee (AEEC). The ARINC 653 is a software specification for space and time partitioning in the IMA architecture. In other words, it defines how an Operating System must guarantee a robust spatial and temporal partitioning. This specification also standardizes the Application Programming Interface (API). The API defined by ARINC 653 is called APEX - APplication Executive.

2.4. APEX - APPLICATION EXECUTIVE

The APEX is a general purpose interface between the Operating System (O/S) and the application software. With this standardized interface, the hardware platform and the software applications can evolve independently of each other, thereby enabling cost-effective upgrades over the life of the system.

3. LITERATURE OVERVIEW

Nowadays, a growing tendency to move from federate architectures to integrated architectures is being performed. The IMA concept is being studied and discussed among engineers from automotive, space and aeronautic worlds.

In the automotive world, federated architectures are formed by ECUs. According to (Di Natale and Sangiovanni-Vincentelli)\(^7\), this kind of architecture is no longer adequate to modern automotive systems due to the ever increasing number of additional features and functions. Moreover, it leads to a proliferation in the number of ECUs, wiring and harnessing, thereby rising size, weight and costs. Thus, they propose the use of integrated architectures to overcome those hurdles.

The aeronautics world is where integrated architectures have reached its highest maturation. Large and visible projects such as Boeing’s 787 and Airbus’ A380 took advantage of IMA concept. Boeing is using its Common Core System (CCS) supplied by GE Aviation to run over 70 separate applications executing at separate safety levels. This architecture allowed Boeing to eliminate over 100 discrete LRUs and shave approximately 2000 pounds (COTS Journal)\(^3\). Likewise, Airbus utilizing IMA approach, cut in half the part numbers of processor units (Avionics Magazine)\(^8\).

(Diniz and Rufino)\(^9\) proposed the use of ARINC 653 standard in space. Their main argument was that most of the requirements from the civil aviation world of ARINC 653 are also requirements from the space world. They also emphasized the benefits in terms of modular certification and usage of Commercial Off-The-Shelf components (COTS).

The European Space Agency (ESA), through Skysoft, developed a multi-platform and modular ARINC 653 Simulator for Modular Space Based Applications (Santos, S. et al)\(^10\).

NASA Langley Research Center presented a research (Di Vito, B.L.)\(^11\) aimed at ensuring safe partitioning and
logical noninterference among separate applications running on a shared Avionics Computer Resource (ACR).

Another NASA center, Ames Research Center, presented a paper (Alena, R.L. et al.) where the authors defined and analyzed suitable architectures, standards and conceptual designs for IMA computational modules for applicability to spacecrafts.

In (Mangieri and Vice), NASA Kedalion engineering analysis lab, along with its Orion prime contractor, validated many contemporary IMA based techniques adapting them into a human space vehicle.

4. IMA CHARACTERISTICS

4.1. ADVANTAGES

4.1.1. Reduced Size, Weight and Power (SWaP)

The IMA concept is based on sharing computing resources, so that the same processor and the associated infrastructure such as power, cooling etc. are used by several applications of different levels of criticality. Reduced hardware means that the size, weight, power and, consequently, cost, are also reduced.

4.1.2. Competitiveness

In Federated Architectures, a supplier of a LRU is responsible for its entire design (hardware and software), implementation, testing and certification of the unit under DO-178B and DO-254. Furthermore, a LRU is typically certified to a single DO-178B and/or DO-254 safety level. Thus, if a new functionality is demanded, the problem is often solved by introducing a new LRU. Moreover, if a simple change in a line of software code is made, a complete requalification of the entire LRU must be done (COTS Journal).

In IMA, the applications are separated from the base computing platform by the APEX. Thus, the base computing platform and the applications can be chosen from different suppliers, thereby given to the airframe manufacture a wider range of options.

4.1.3. Portability and Reuse

With the APEX intermediating applications and computing platforms, standard modules for common tasks that could be reused by different functions running on different platforms could be created. These modules could be interchangeable among various systems. Thus, as these modules would be produced in large scale, the cost would be reduced.

4.1.4. Incremental Certification

ARINC 653 robustness allows incremental certification because hardware and software are truly isolated. Thus, differently of federated architectures, in integrated architectures, it is possible to modify a certified system by certifying only the changes. It is not necessary to repeat the full certification process again. Furthermore, application of different levels of criticality can be certified in the same module.

According to (Gangkofer, M. et al.), it is necessary to identify and constrain the effects of the modifications. Thus, the incremental certification can be achieved.

4.1.5. Resource Allocation

Integrated architectures based on the IMA concept utilize configuration tables to allocate the shared computing resources to the hosted functions. Manipulating the configuration tables, the system integrator has the flexibility to dynamically manage spare resources to each individual hosted function. IMA has an additional capability to reserve a spare resource pool to be allocated to any hosted function. Thus, the system integrator is able to vary, within certain limits, the resource allocation for a given hosted function in the future; or to add new hosted functions without the necessity of adding new computing resources.

The resource allocation is not made while the system is utilized in service because of certification issues. However, it can be dynamically re-allocated through updated system configuration data; and then be certified for use in service (Watkins and Walter).

4.1.6. Reconfiguration and Robustness

In this architecture, the modules are software-configurable and there is a potential path between any of them. These features allow them to respond to avionics faults. Thus, they can adapt to changes in network functioning or operating modes so that, in the event of failures, the system can reconfigure its software functions in pre-determined ways (Alena, R.L. et al.).

4.2. DISADVANTAGES

4.2.1. Complex Integration Process

In IMA architectures the base platform and the application are separated so that they can be provided by different suppliers. Therefore, it generates a more complex process of integration. According to (Watkins and Walter), before transitioning from federated architectures to IMA architectures, the system integrator must be confident in its ability to perform the integration process, which includes increased interface definition & management, resource allocation & management, and system configuration analysis & generation.
5. CONCLUSION

This paper presented an overview of the Integrated Modular Avionics concept emphasizing its advantages in relation to federated concepts. Furthermore, it was shown who is involved in the study of IMA architectures and where they intend to apply IMA concepts.

For future work, we intend to simulate and present a control system making use of an IMA Simulation tool as part of a Master Degree in progress.

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7. REFERENCES