Open Systems Integrated Modular Avionics
– The Real Thing –

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ABSTRACT

The last decade several definitions of integrated modular avionics have been developed. This paper starts with the basic definition of open systems and will then focus on the trends in avionics architectures which will ultimately lead to the development of real open systems integrated modular avionics. The basic principles are explained, including both advantages and disadvantages.

1.0 INTRODUCTION

Avionics can be defined as the science and technology of electronics applied to aeronautics and astronautics or the electronic circuits and devices of an aerospace vehicle. Almost two decades ago a new concept was introduced within the avionics technology: integrated modular avionics (IMA). Up to now this definition has been used for many installations onboard new aircraft types. This paper describes the basic principles of IMA and will focus on the optimal situation in which open systems concepts are combined with IMA. Pros and cons are considered for different implementation techniques.

2.0 DEFINITION OF OPEN SYSTEMS

Before getting into the details of avionics architectures first the term "open systems" needs to be defined. When looking at the basic definition an open system is an architecture (design) whose specifications are public. Emphasis must be put on the fact that the specifications of an open systems architecture are not proprietary. It is of course allowed to use officially approved standards as well as privately designed architectures whose specifications are made public by the designers.

3.0 TRENDS IN AVIONICS ARCHITECTURES

The past

The traditional implementation technique for avionics can be characterised as federated, which means that each aircraft function consist of a stand-alone composition of sensors, processing units and actuators. In general data is not shared between different functions. Therefore, when looking at the avionics bay of aircraft for which the avionics suite was developed in the 20th century all contain identifiable units or "boxes" with one specific function, for example an inertial navigation system, an auto-pilot, a flight management system, a breaking and anti-skid system, etc.

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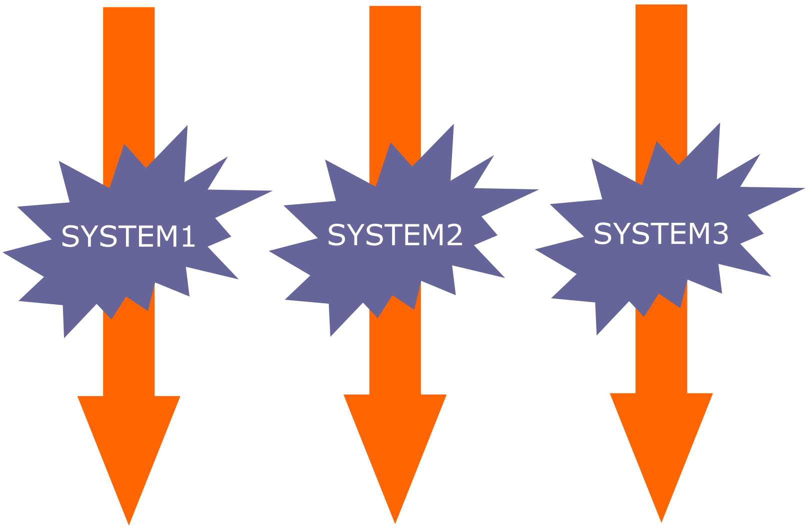


Figure 1: Federated architecture: no sharing of data

Characteristics of these federated architectures (Figure 1) are that each system has its own interfaces to sensors and actuators. Data is not shared, therefore providing intrinsic partitioning of functions. The interfaces consist mostly of ARINC429 data communication and specific analogue or discrete signals.

The disadvantage of these kind of technology is the fact that each box has a specific function, with specifically developed hardware and software. Each system is more or less developed from scratch, with the lack of technology re-use. Especially the hardware component suffer from obsolescence issues. Another disadvantage is the increased weight and power consumption due to the fact that each unit carries the burden of environmental protection and inherent power dissipation issues. Moreover, looking at the logistics consequences of federated systems, it implies a very non-efficient way of handling spare parts because systems are not interchangeable.

Today

Today's modern avionics systems architectures contain a high level of integration (Figure 2). Sensor data is shared between several systems. Even modularity is introduced to a certain extent, especially on hardware module level. In fact it has been an avionics supplier choice to provide a completely integrated modular avionics system to the aircraft integrator. In most cases there is a core computer that performs the majority of avionics functions. Looking inside this core computer several modules can be identified performing a specific function, like display modules, flight management modules, auto pilot module, etc.

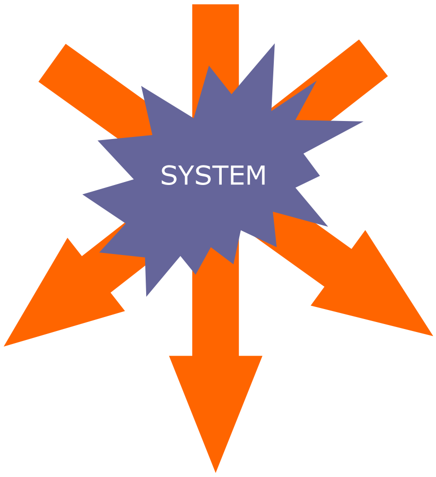


Figure 2: Integrated system: sharing data

A characteristic of these line replaceable modules (LRMs) is that they are developed according to proprietary standards defined by the supplier. To ease maintenance, and to a certain extend reduce the hardware obsolescence risk, modules have a standard physical layout that fits within a standard modular housing, which in it self in most case is again a LRU. Still, an advantage for these integrated modular architectures is the intrinsic partitioning between aircraft functions, which ease the certification process. Another characteristic is the use of modern digital avionics busses, like ARINC659, ARINC629, MIL-STD 1553 and other proprietary busses.

The fact that in these modern architectures there is still a strong connection of aircraft function to a module prevents the inter-changeability of different modules. This also implies obsolescence issues. Another disadvantage is that mostly proprietary standards are used, making the changes very expensive and introducing a supplier monopoly, as competition is not possible.

The future

The trend in avionics system architectures is towards general purpose avionics computers which are defined as platforms. A platform in itself is not performing any avionics function, but provides communication, computing and memory resources to the avionics (software) applications (see Figure 3). In fact this is fully in line with the desktop personal computer (PC) technology which is common today: the PC provides the required resources (hardware, communication, memory, operating system services) to the applications.

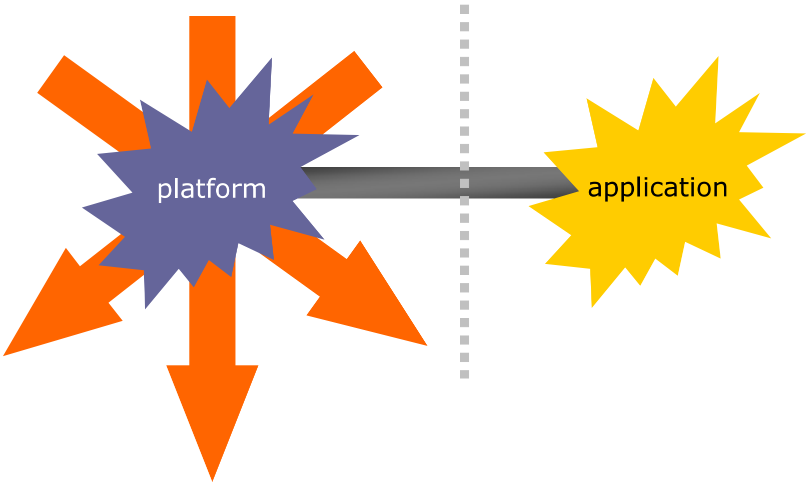


Figure 3: generic platform provides resources to applications

The platform is a generic processor hosting several system functionality. The core software inside the platform provides the partitioning of the functions, which can now be distributed across the architecture. The platforms are common digital modules or units with standard input/output interfaces. Data communication throughout the architecture can take place with data networks like Avionics Full Duplex Switched (AFDX) ethernet. Still, legacy equipment is involved and therefore interfaces are required to interface with this equipment. The trend is that all data coming from legacy equipment or sensors, and all data sent to legacy equipment or actuators, is translated from/to the standard data network (see Figure 4).

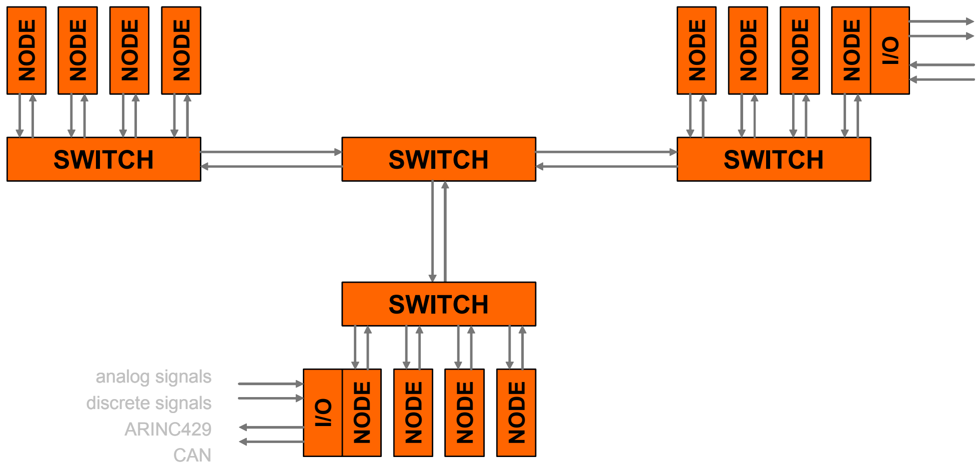


Figure 4: Packet switched networking

Once data is translated to a packet switched network (analogous to local area or internet networks), the network itself can be configured in such a way that the information is routed anywhere within the architecture. This eases system integration issues.

4.0 THE REAL THING

Generic platform with open systems interfaces

Ideally each avionics computer has a standardised open systems interface, which is defined as an application programming interface (API). Preferably this API is a defined standard like ARINC653. When such an API is used third parties can develop applications for the platform, enhancing competitiveness of both avionics platform and application suppliers.

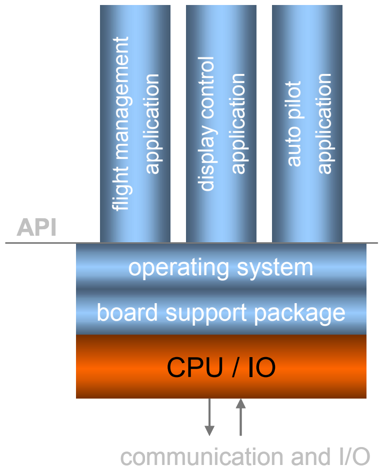


Figure 5: Architecture of avionics computer

As depicted in Figure 5 a platform can host several aircraft applications which is mostly software but could also include application specific hardware. Furthermore, the software applications are fully isolated by partitioning mechanisms. Partitioning enables a safe sharing of the processing resource (time), the memory (space) and communication means (input/output).

Flexible communication means

In this ideal situation it does not matter where the applications are hosted, as long as they get their required resources. When looking at the communication this means that there is now a logical channel and a physical channel for communication.

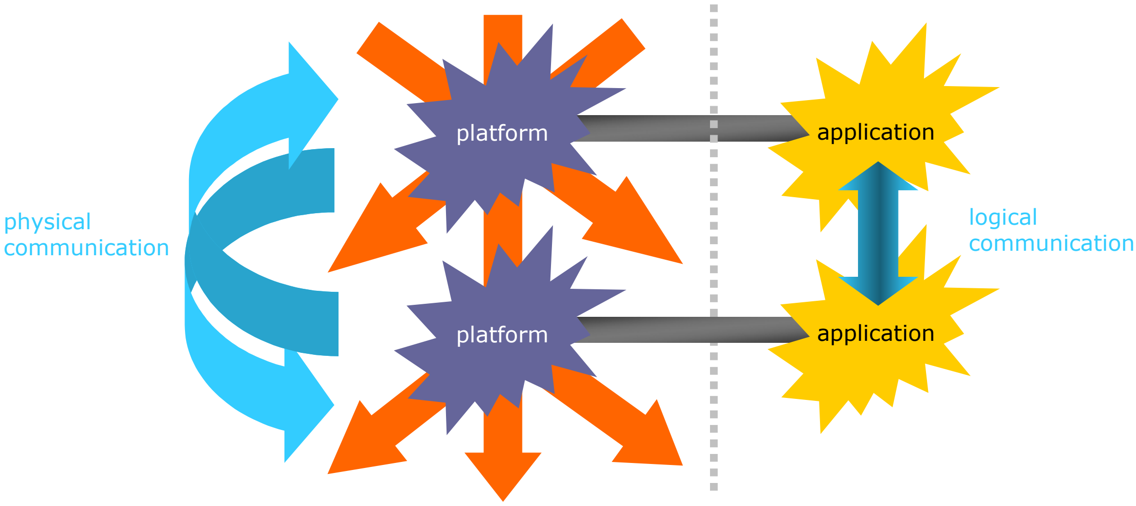


Figure 6: logical and physical communication

Applications will send and receive their data through logical ports (see Figure 6). They are not aware that the platform on which they are hosted is taking care of the physical communication. The application can be on the same platform, but can also be hosted by another platform somewhere in the network.

Rack or unit approach

In addition to flexible communication means the open systems integrated modular avionics architecture also provides flexibility in hardware architecture. The platforms can be build as modules that have to be placed into a environmentally conditioned rack, or the platform itself can be a completely integrated unit.

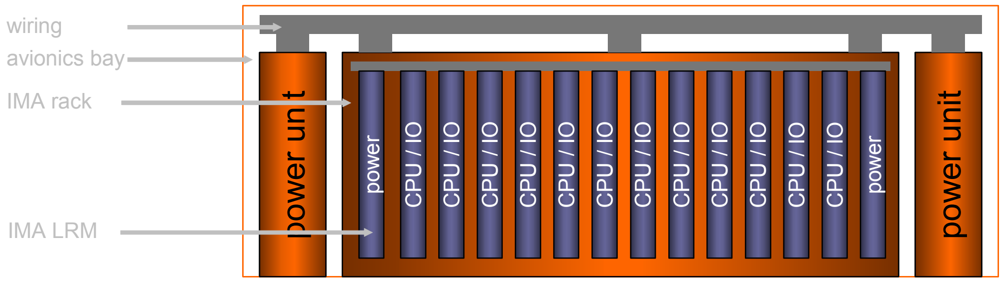


Figure 7: IMA rack approach

With the rack approach (Figure 7) the rack itself is a line replaceable unit (LRU) and the platforms consist of line replaceable modules (LRM) inside this rack. The advantage of this approach is the reduced weight and optimised power consumption because the platforms share one box that provides environmental protection and provides conditioned power. Disadvantage of this approach is that the rack needs to be opened to replace platform modules. In most cases this cannot be performed during regular maintenance, which means that the complete rack needs to be taken to the maintenance shop.

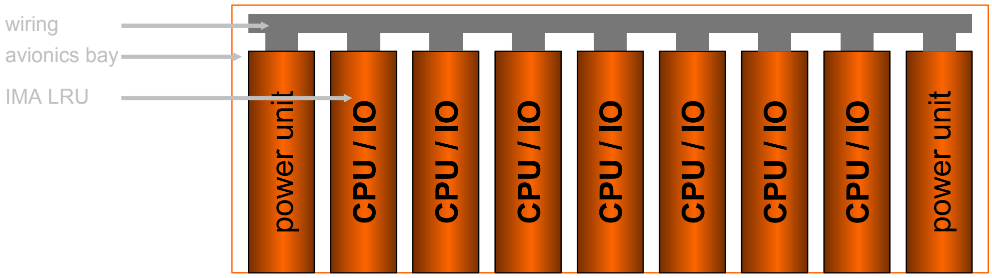


Figure 8: IMA unit approach

With the unit approach (Figure 8) each platform is contained within a completely integrated line replaceable unit (LRU). Each self-contained avionics computer has now its own box, power supply and environmental protection. This approach eases the maintenance process as the LRU having a problem can be easily taken out of the avionics bay and replaced by another.

Fault tolerance

Another potential property of a modular avionics system is fault tolerance. As it is less important where the applications are hosted and the fact that applications are not ware of each other, enables the mechanism for a fault tolerant architecture. An application can be instantiated more than once, creating redundancy in the system (Figure 9).

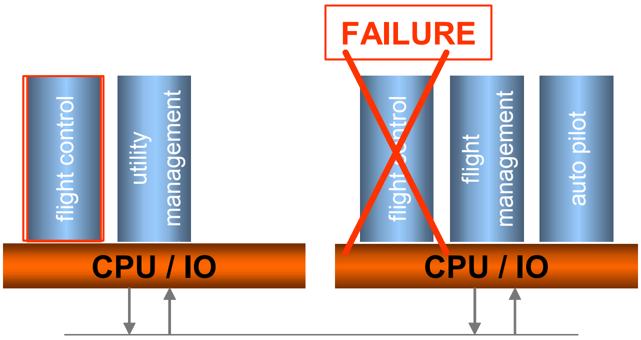


Figure 9: IMA fault tolerance

Of course the platform must be aware of this replication and must also have the mechanism to manage the multiple instantiation. But once that mechanism is put in place, building a fault tolerant architecture is just a matter of defining the correct configuration tables.

5.0 PROS AND CONS

The open systems integrated modular avionics architecture has both advantages and disadvantages. The pros are the following:

- The avionics computer platforms as standard building blocks are interoperable and plug-and-play.
- It is possible to mix components from different suppliers which increases competitiveness.

- Most engineering cost will be at the application level where the complex functionality is located. As there is now a clear interface between the applications and the underlying computer platform there is a reduced hardware obsolescence issue. Platforms can be replaced and the expensive (mission) software can be reused.
- If the platform is developed according to open standards it is possible to have third-party application and add-on development. This increases flexibility in supplier selection.
- The platforms contain configuration tables to define application resource allocation and communication infrastructure. With open systems modular avionics this provides a flexible design that can be changed and optimised in a late stage during development.

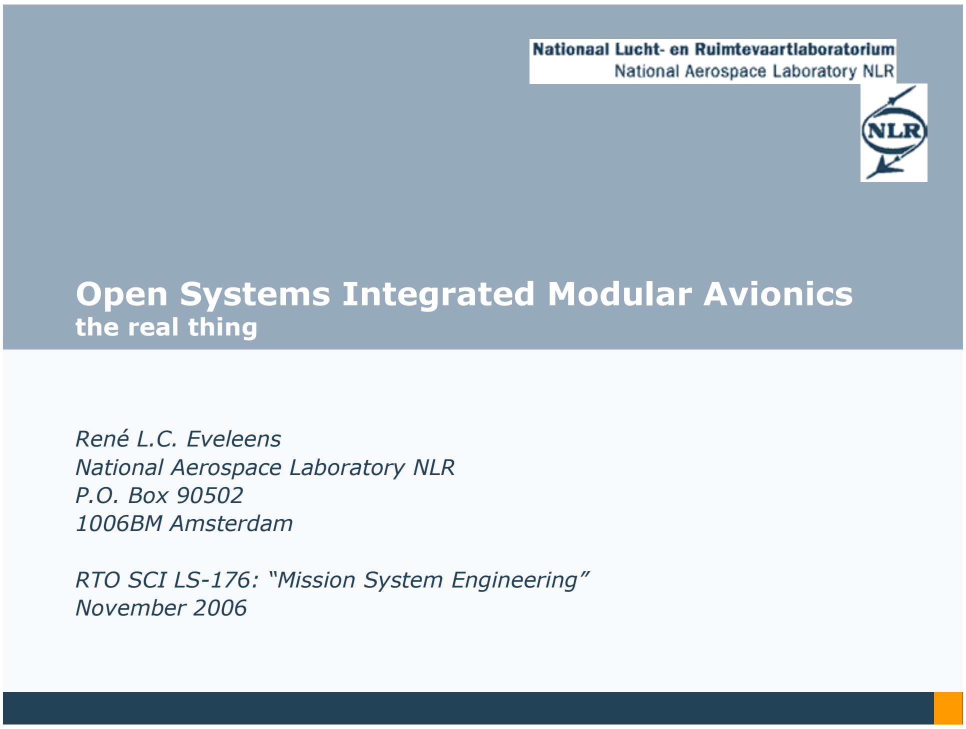
The cons are:

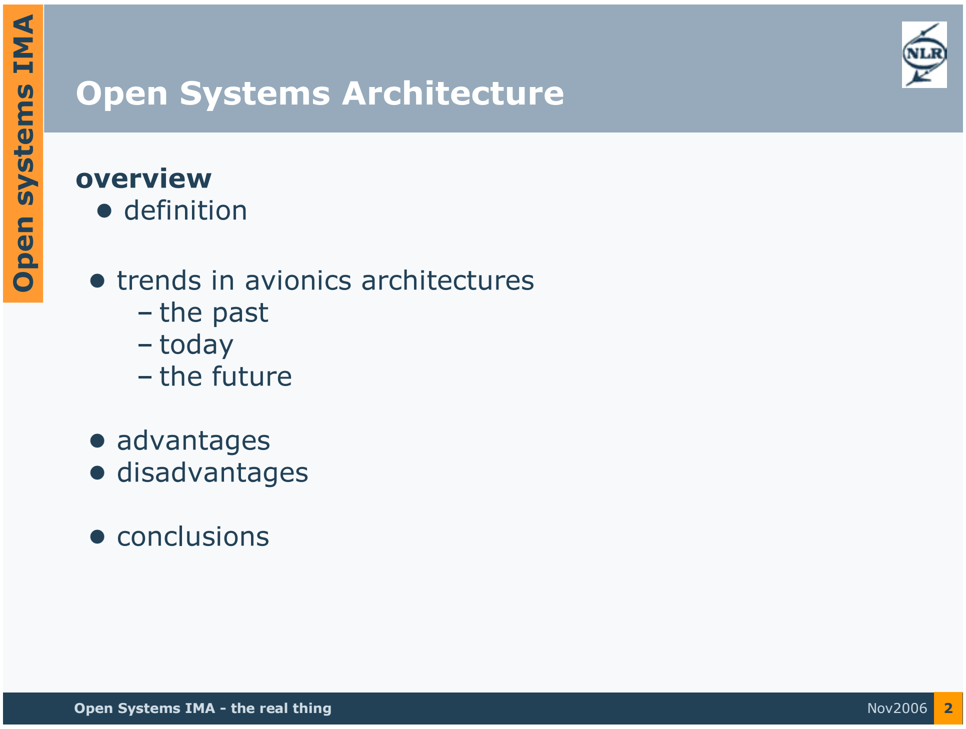
- Different building blocks of the system architecture may be provided by different suppliers. In order to develop an application on top of a platform, all information needs to be public. This faces a challenge with respect to intellectual property rights (IPR). Suppliers want to protect their knowledge and will not easily provide all required information.
- An issue related to the previous one is the integration responsibility. The architecture building blocks strongly depend on each others performance. Module suppliers cannot take the full system responsibility. At the same time application suppliers depend on the platform performance but is not their responsibility. Adding the qualification and certification issues to this even increases the challenge.
- The use of third-party equipment and software can become an issue. Most of the time it is unclear if the documentation is accurate and complete. Moreover in most cases it is not easy to transfer the required design data.
- It is generally stated that standardisation contradicts high performance. A standardised programming interface (API) is never optimised for a certain application and will introduce additional overhead in the system. The same is valid for standardised communication.
- The configuration tables, which are mentioned in the pros above, also has a less positive side. In a complex architecture a lot of parameters need to be managed. Configuration consistency and completeness is a challenge.

6.0 CONCLUSIONS

In general it can be concluded that a new technology for avionics architectures is required in order to counter hardware component obsolescence issues and increase system flexibility. The modular avionics architectures implemented today are mostly proprietary. The new trend is "open systems", where common digital modules and/or units with a standardised operating system build the architecture. The aircraft functionality performed by the software applications. For data communication the trend is towards airworthy ethernet (e.g. AFDX).

ANNEX: PRESENTATION SLIDES





Open systems IMA

Open Systems Architecture

definition

- architecture (design) whose specifications are **!!! public !!!**
- this includes officially approved standards as well as privately designed architectures whose specifications are made public by the designers
- the opposite of open is closed or proprietary

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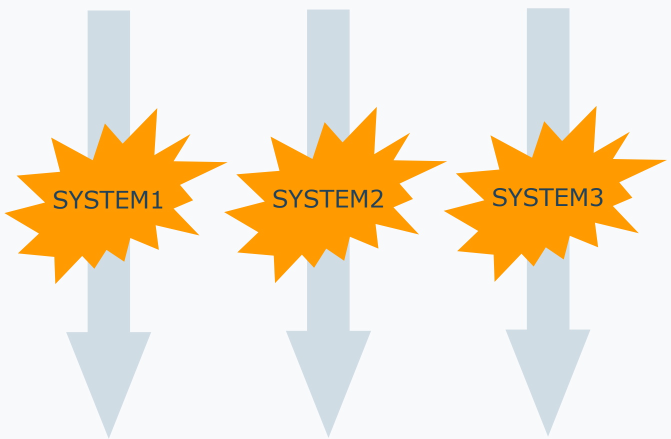
Trends in avionics architectures: the past



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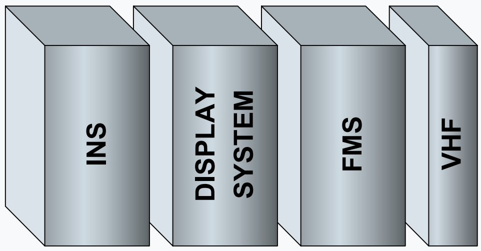
Trends in avionics architectures: the past

avionics systems in the past

- "federated" avionics systems
  - independent avionics components with specific function
  - systems together build up aircraft functionality
- line replaceable units (LRU's)
- intrinsic partitioning, one processor per system functionality



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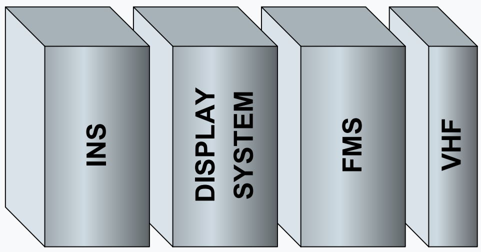
Trends in avionics architectures: the past

interfaces

- dedicated I/O
  - ARINC 429 (point to multi-point, asynchronous)
  - discrete signals
  - analog signals



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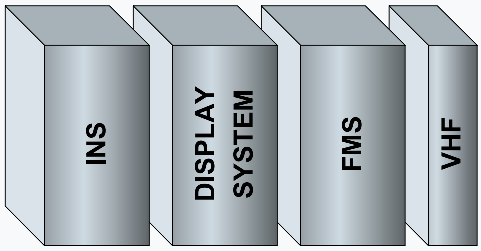
Trends in avionics architectures: the past

disadvantages

- specific function for each box
- specific hardware and software
  - obsolescence of hardware components
  - little re-use of technology
- weight and power consumption
  - shielding per unit
  - power per unit
- maintenance
  - spare parts
  - not interchangeable



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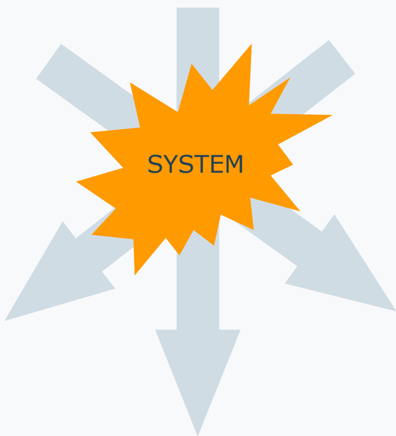
Trends in avionics architectures: today



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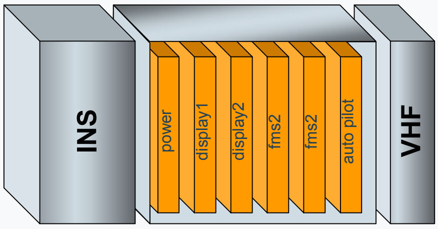
Trends in avionics architectures: today

avionics systems today

- integrated modular avionics (IMA)
  - line replaceable modules (LRM's)
  - proprietary standard physical module layout (interface, form, fit)
  - proprietary standard modular housing (LRU)
- intrinsic partitioning, one processor per system functionality



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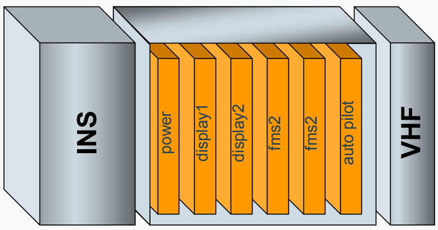
Trends in avionics architectures: today

interfaces

- dedicated I/O still used (robustness, availability)
- backplanes
  - ARINC 659 or proprietary busses
- system busses
  - ARINC 629 (lock step, distributed control)
  - MIL-STD 1553 (command / response using bus controller)
  - proprietary busses



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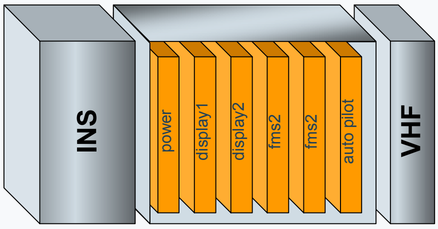
Trends in avionics architectures: today

disadvantages

- specific function for each LRM
  - auto-pilot module, flight management module, etc.
  - not interchangeable
- specific hardware and software: obsolescence of components
- proprietary standards
  - changes are expensive
  - supplier monopoly
  - no competition



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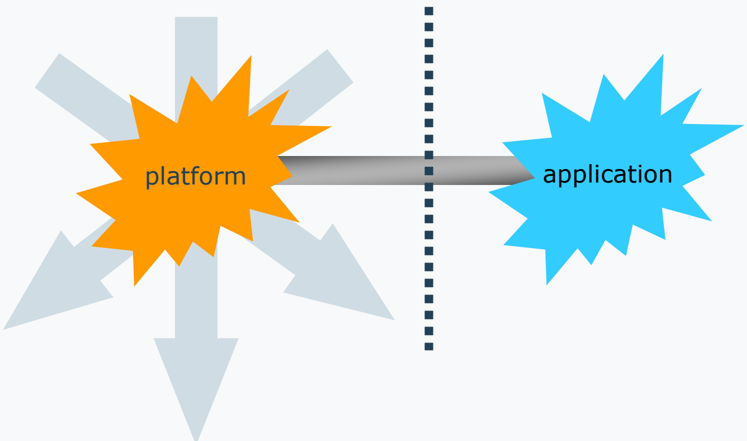
Trends in avionics architectures: the future



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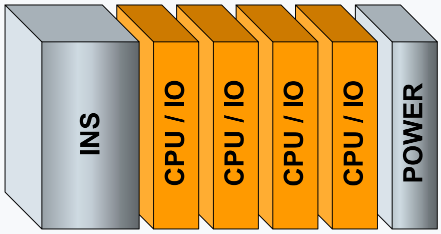
Trends in avionics architectures: the future

avionics systems in the future

- open systems integrated modular avionics
- generic processor hosting several system functionalities
- partitioned software distributed across the system
- common digital modules / units with standard I/O



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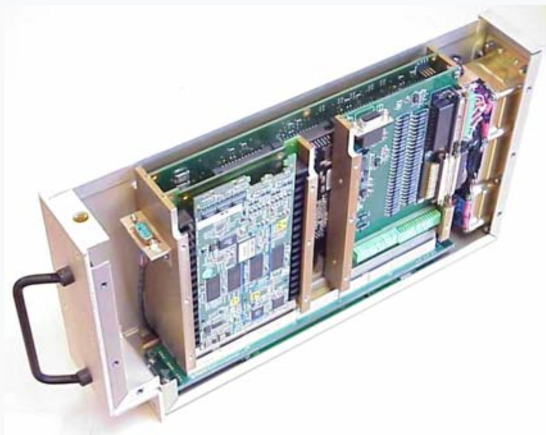
Trends in avionics architectures: the future

CPU / IO module



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Trends in avionics architectures: the future

interfaces

- packet switched networking
  - e.g. Avionics Full Duplex Switched ethernet (AFDX)
  - all modules / units can talk to each-other (flexible!)

- dedicated I/O
  - interface to legacy equipment
  - interface to dedicated sensors / actuators
  - **all translated to standard network !!!**

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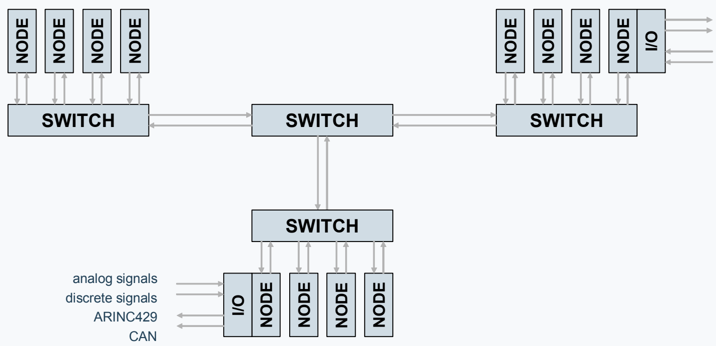
Trends in avionics architectures: the future

interfaces

- packet switched networking (e.g. AFDX)
  - local area network (LAN)



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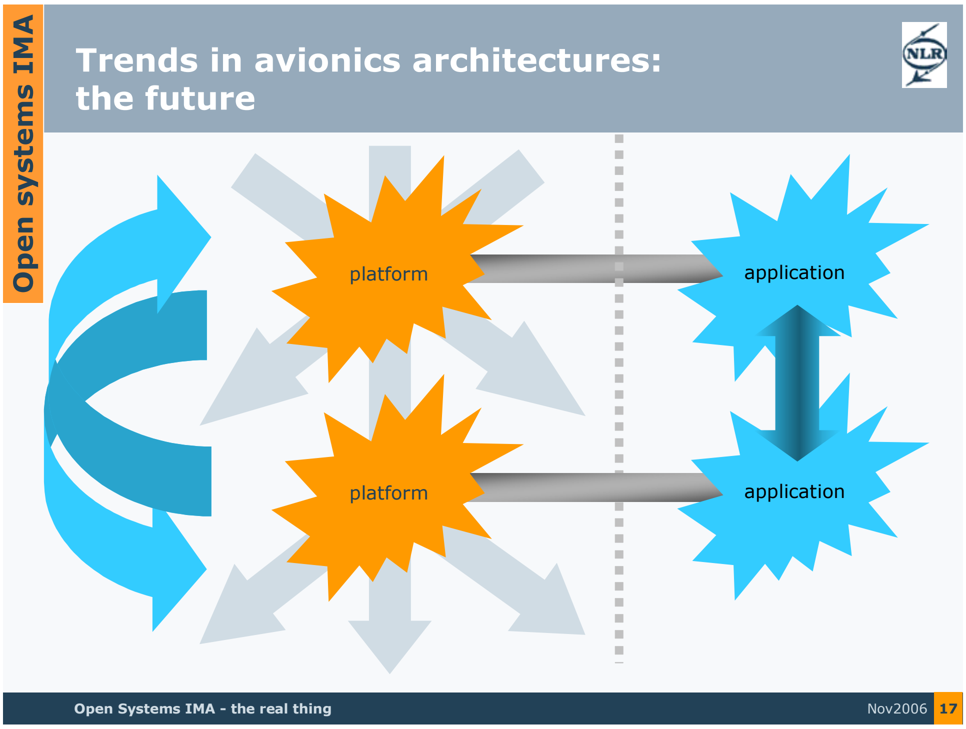
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Trends in avionics architectures: the future
NLR
platform
application
platform
application
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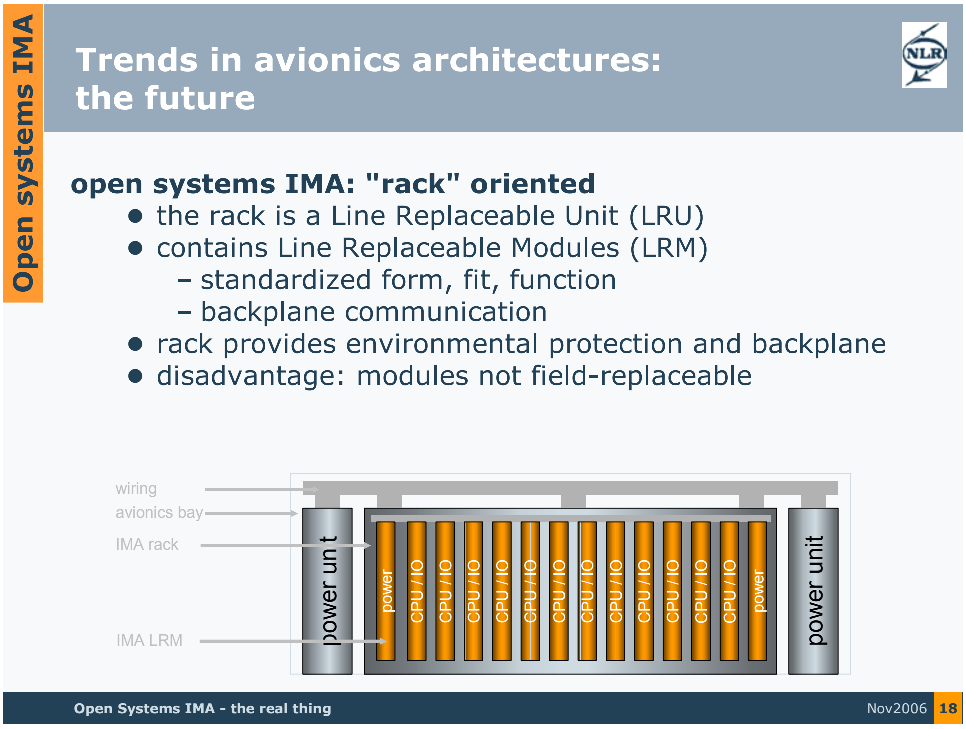
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Trends in avionics architectures: the future
NLR
open systems IMA: "rack" oriented
● the rack is a Line Replaceable Unit (LRU)
● contains Line Replaceable Modules (LRM)
– standardized form, fit, function
– backplane communication
● rack provides environmental protection and backplane
● disadvantage: modules not field-replaceable
wiring
avionics bay
IMA rack
IMA LRM
power unit
power
CPU / IO
power
power unit
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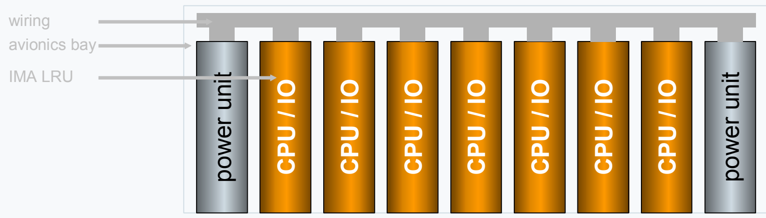
Trends in avionics architectures: the future

open systems IMA: "unit" oriented

- each module is a Line Replaceable Unit (LRU)
- the unit has its own environmental protection
  - housing / EMC / lightning
  - disadvantages with respect to cost / weight
- units are connected by avionics bay wiring



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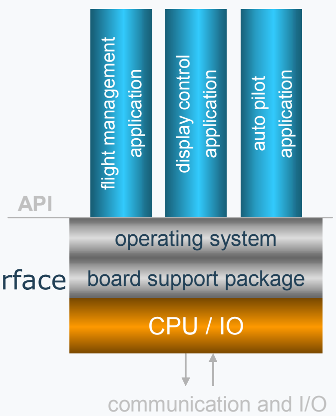
Trends in avionics architectures: the future

standardized digital modules / units

- host several aircraft applications (software)
- fully isolated software partitions
- standardized operating system
  - scheduling, communication, health monitoring
- hardware resource sharing
  - processor (CPU)
  - memory
  - communication and I/O
- application portability
  - application programming interface (API)



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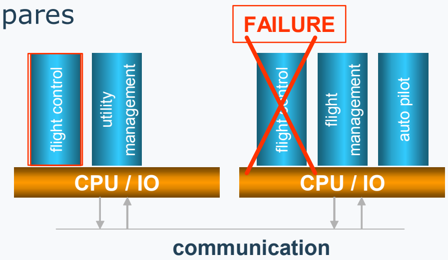
Trends in avionics architectures: the future

fault tolerance

- providing fault detection, localization and isolation
  - health monitoring in each partition
  - global fault manager identifying the problem
  - "brick-wall" software partitioning
- reconfiguration possible
  - with static predetermined configurations (determinism)
  - "hot" or "cold" spares



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Open Systems Architecture

definition (again)

- architecture (design) whose specifications are **!!! public !!!**
- this includes officially approved standards as well as privately designed architectures whose specifications are made public by the designers
- the opposite of open is closed or proprietary

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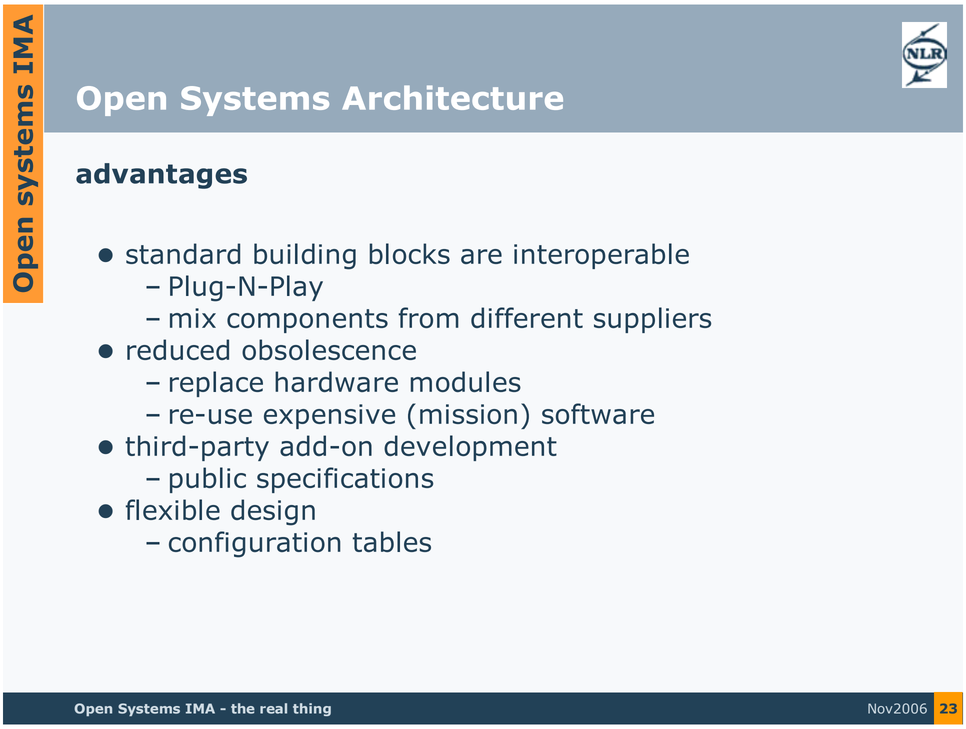
Open systems IMA
Open Systems Architecture
advantages
● standard building blocks are interoperable
– Plug-N-Play
– mix components from different suppliers
● reduced obsolescence
– replace hardware modules
– re-use expensive (mission) software
● third-party add-on development
– public specifications
● flexible design
– configuration tables
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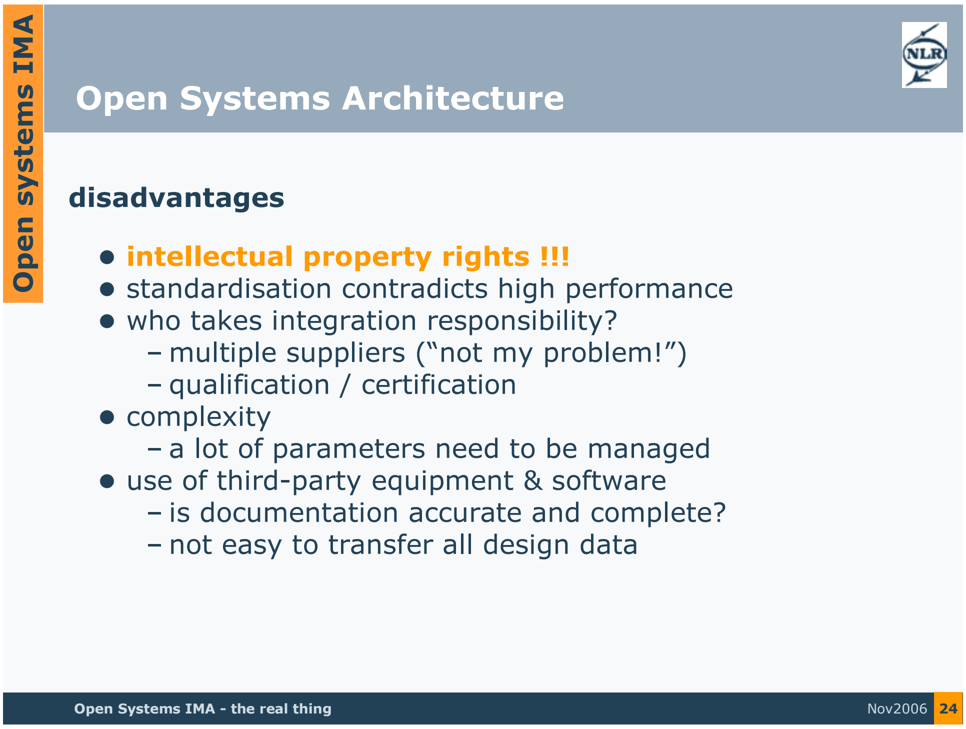
Open systems IMA
Open Systems Architecture
disadvantages
● intellectual property rights !!!
● standardisation contradicts high performance
● who takes integration responsibility?
– multiple suppliers ("not my problem!")
– qualification / certification
● complexity
– a lot of parameters need to be managed
● use of third-party equipment & software
– is documentation accurate and complete?
– not easy to transfer all design data
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Open Systems Architecture

conclusions

- new technology for avionics architectures required
  - hardware component obsolescence
  - architectures today is mostly proprietary
- new trend is "open systems"
  - common digital modules / units with operating system
  - aircraft functionality performed by the software applications
  - interfacing trend towards ethernet (e.g. AFDX)
- be careful if a supplier states to have an "open system"
  - is it really a public standard that is used?
  - **what is in it for you?**