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SB 503 - Avionics Technologies
2- Platforms & Integrated Modular Avionics (IMA)

2-1 IMA Historical background
2-2 IMA Introduction & Overview
2-3 IMA System, Actors & Roles
2-4 IMA Solutions, Modules & Tools
2-5 IMA Certification Process Overview
2-6 Performances & Determinism – EVT

Professor: H. GOUTELARD (Contractor ENAC/Sup'Aéro)
Thales Avionics

2-1 IMA Historical Background

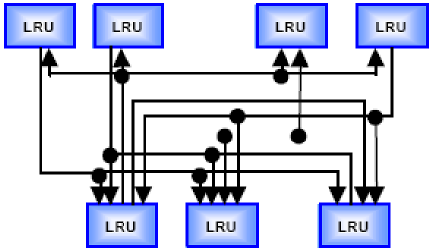
Why IMA ?

•Since the 1970's, 2 tendencies observed program after program:

- Increase of complexity
  - Increase the number of equipments installed on aircraft
  - Increase the number of wires to interconnect all equipments
- Higher level of requests and constraints
  - Time to market
  - Safety
  - Performances

•Between 1990's and 2000's, capability to integrate several applications inside a unit is reached

- IMA is identified as a concept permitting to
  - Reduce the number of equipments installed on aircraft (Integrated)
  - Reduce the number of types of equipments installed on aircraft (Modular)
- IMA appears as a mean to reduce the overall cost of eletronics infrastructure on aircraft
  - Reducing overall development and recurring costs
  - Reducing overall maintenance costs



- One LRU = One function
- ARINC 429 Network (100Kbps)

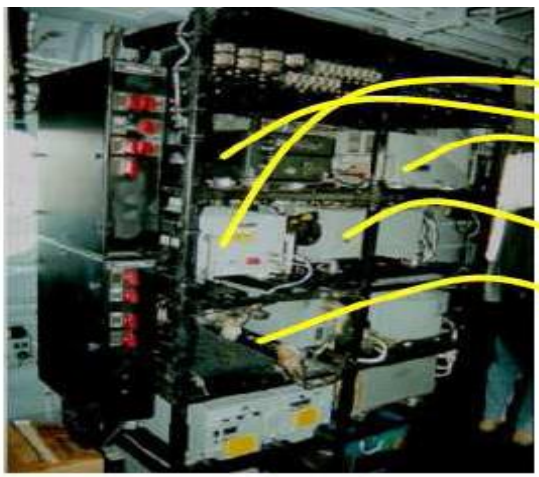
Integrated Modular Avionics (IMA)

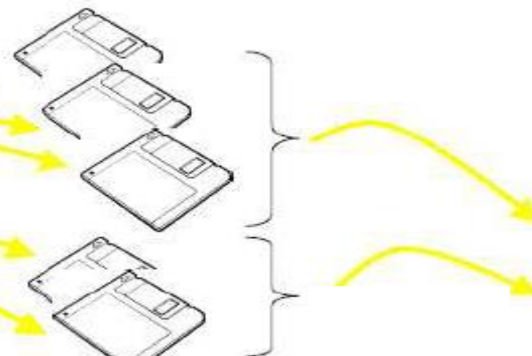
Federated Solutions

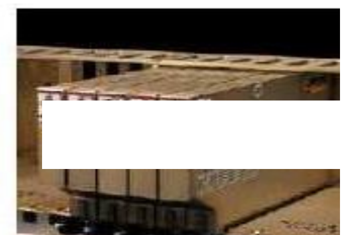
1 function = 1 computer

IMA Based Solutions

Platform composed by a set of non system specific and highly configurable computers

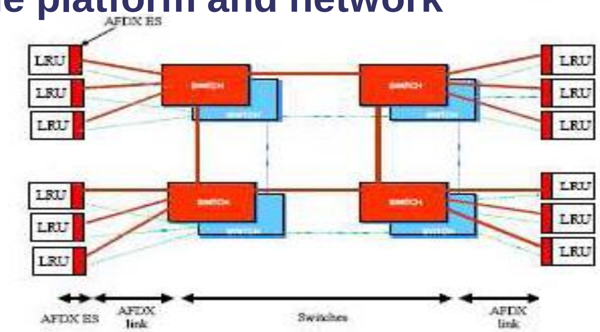






Multiple systems applications are executed on the same platform and network

ARINC 429



Allowing highly integrated architecture, IMA permits recurrent, development and maintenance cost savings while reducing volume and weight

IMA origins

•Definition:

- Firstly defined by ARINC 651 in 1991
- formalized by EUROCAE and RTCA WG60/SC200 in 2005

•Main benefits expected:

- Scheduled maintenance and reduced number of spares
- Global reduced cost: development, certification and production

•Main Characteristics identified:

- Standardized interfaces
- Shared resources and Partitioning
- Application Software functional independence
- Fault tolerance

•Major programs:

- First use in B777
- Confirmed by A380, A400M and B787 and A350

Integration and Modularity

- **Integrated (I)**
  - Multiple systems applications executed on the same computer
  - Data communications multiplexed onto a high speed multiplexed network

- **Modular (M)**
  - A set of standard non system specific computers
  - Computers that can be configured to provide part of their resources to a particular system application

- **IMA Platform**
  - IMA is a Concept supported by standards
    - Interfaces (A653)
  - Multiple platforms for one concept
    - CPIOM
    - RACK with blades
    - etc…

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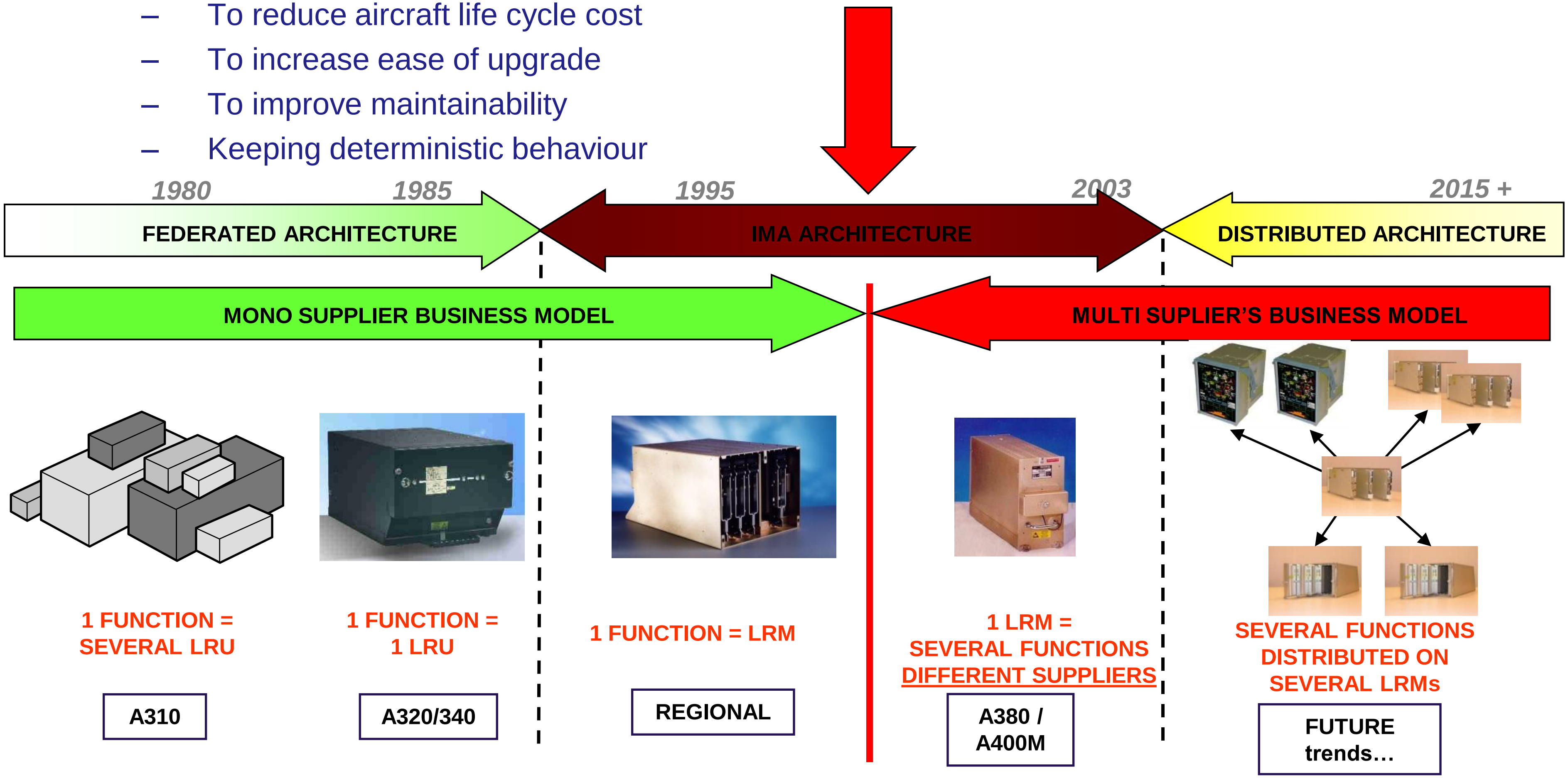
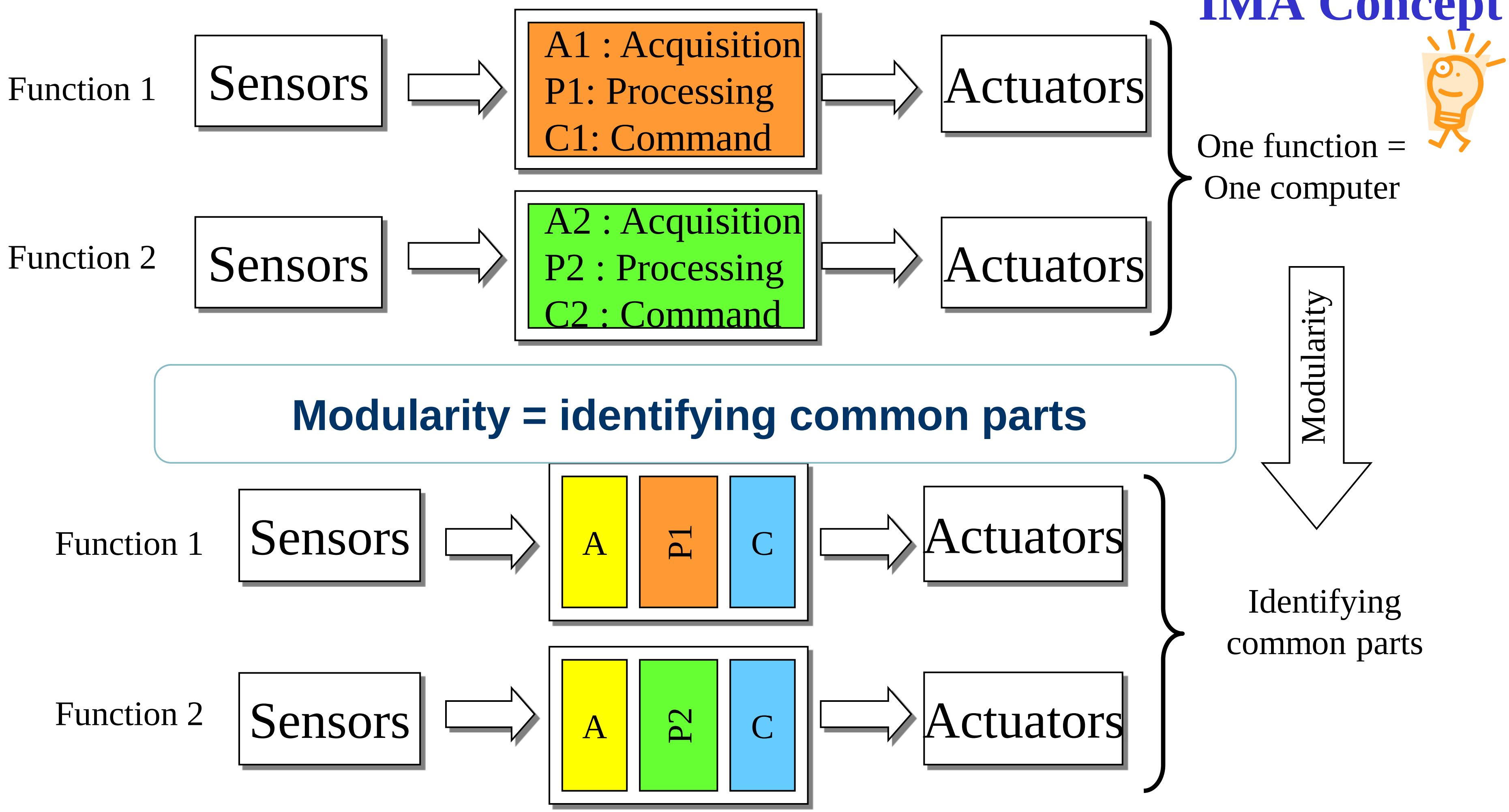
- 30 years of architecture evolution to contribute
  - To boost performances
  - To reduce aircraft life cycle cost
  - To increase ease of upgrade
  - To improve maintainability
  - Keeping deterministic behaviour



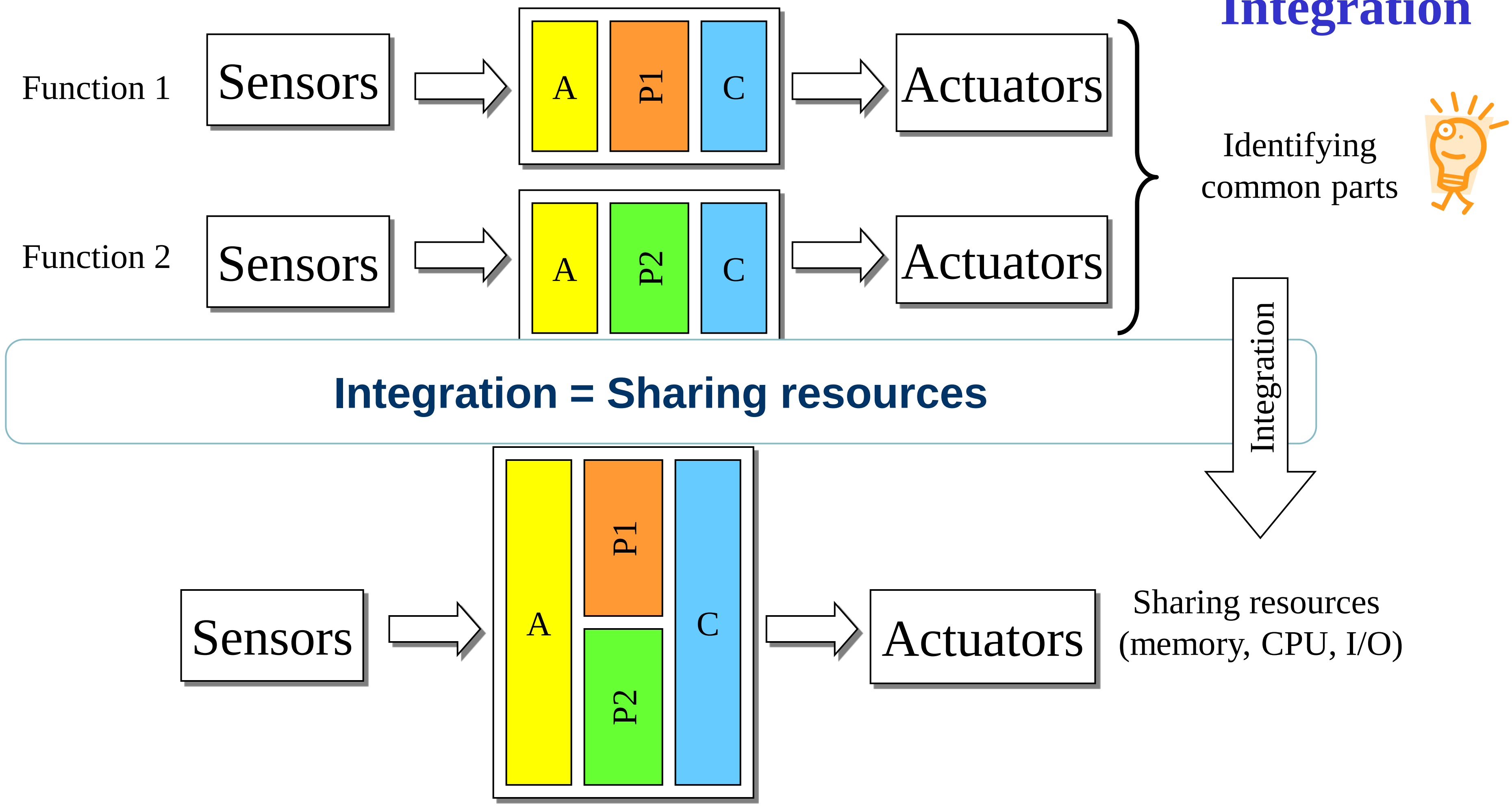
THALES AIRBUS GROUP SAFRAN

2-2 IMA Introduction and Overview

IMA Concept


Function 1
Sensors
A1 : Acquisition
P1: Processing
C1: Command
Actuators
Function 2
Sensors
A2 : Acquisition
P2 : Processing
C2 : Command
Actuators
One function =
One computer
Modularity
Modularity = identifying common parts
Function 1
Sensors
A
P1
C
Actuators
Function 2
Sensors
A
P2
C
Actuators
Identifying
common parts

Integration



Benefits

- Single interface for applications (API)
  - Portability (reuse) and upgradeability
  - Independence from hardware (obsolescence)
  - Commonality of development, test efforts and tools
- Less weight, volume and power supply consumption
- Less spare to Maintain & Manage for Airliners

Less spare to maintain + independence from HW

2-3 IMA System, Actors & Roles

IMA Constraints & Must

- Resources: Independence between Apps
  - Robust partioning DO 248, DO 297

- Process:
  - To organize & to allocate resources
  - Ensure integration (All Apps together on the same platform…) ← Major stake in the IMA process for Cert.

IMA Actors & Roles

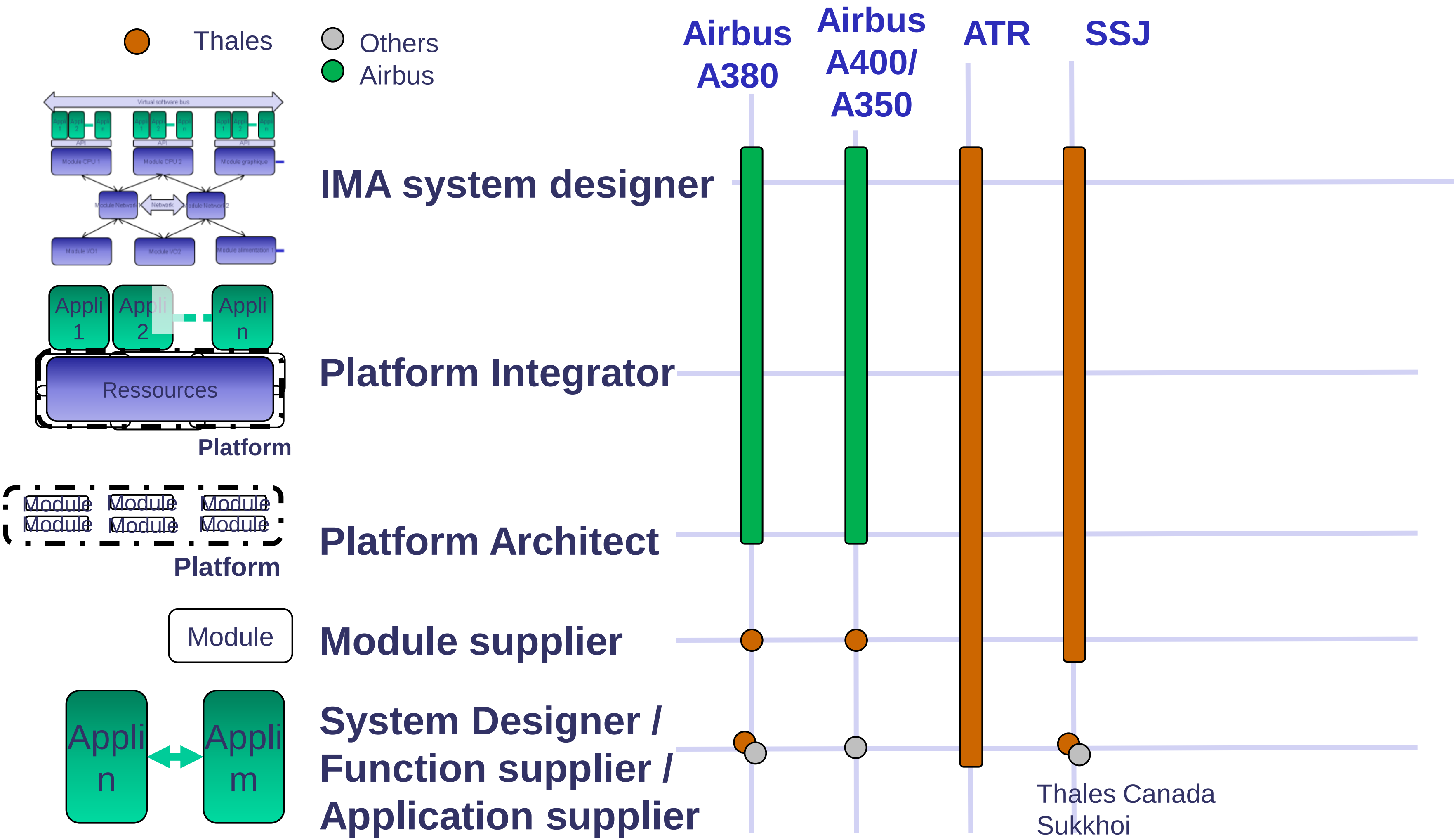
- **Platform / module Supplier**
  - H/W & Core S/W Supplier that includes Robust Partionning
- **Avionics System / Function Supplier**
  - Application Supplier including integration on the plateform
- **Platform Integrator**
  - Organize resources distribution
  - Resources allocation
  - Ensure integration (Apps together on the same plateform)

Design constraints

- All functions are
  - Hosted via common API (ARINC 653)
  - Connected via a common bus (ARINC 664 / AFDX)
- Basic software developed in DO-178B/C A level
  - In order to host functions up to DO-178B/C A level
- Robust partitioning between functions
  - Heterogeneous DAL levels (A ➔ E)
  - Partitioning that includes all resources types
    - In time, memory and I/Os

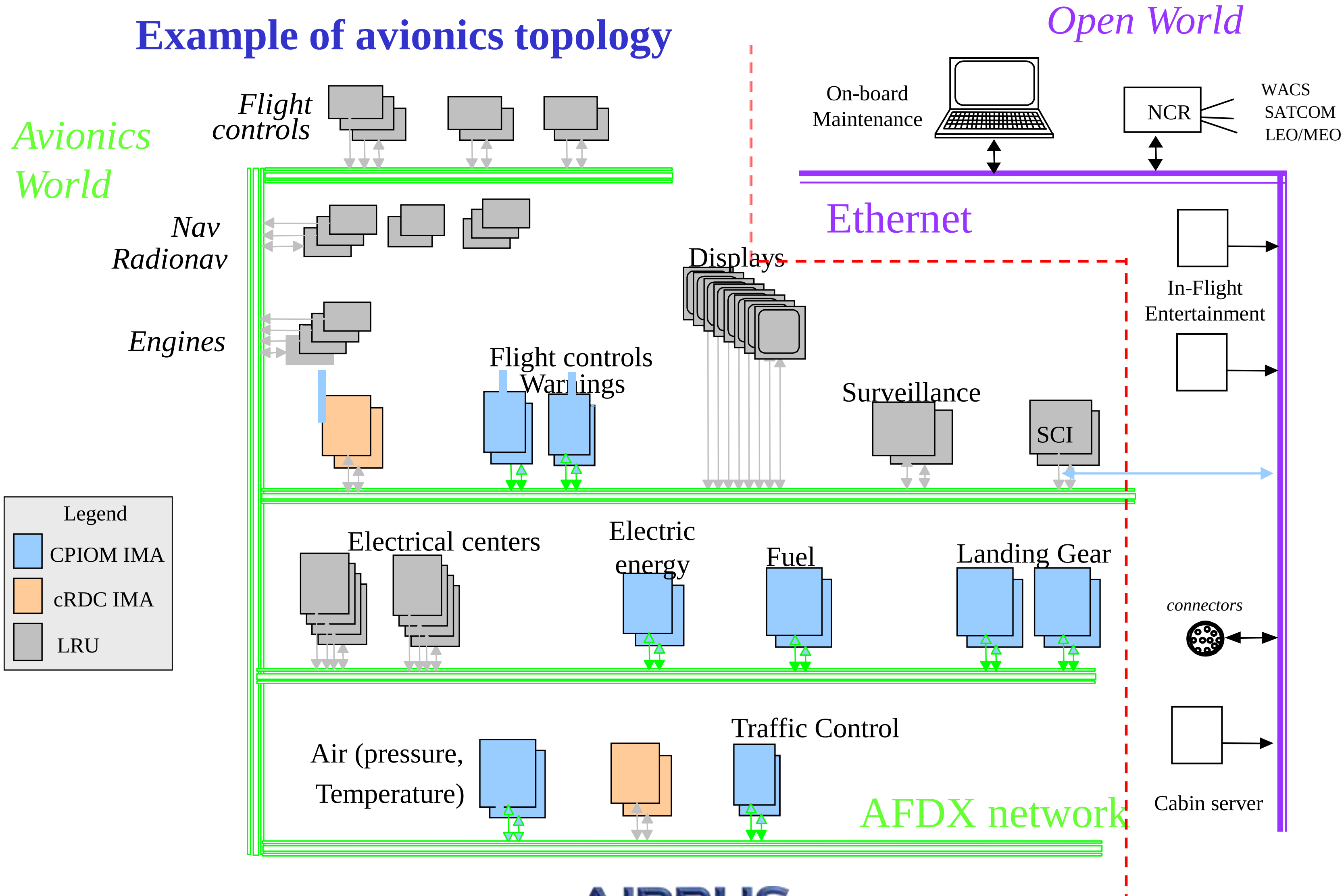
Partitioning is the key constraint in IMA

Maket Actors & Positionning

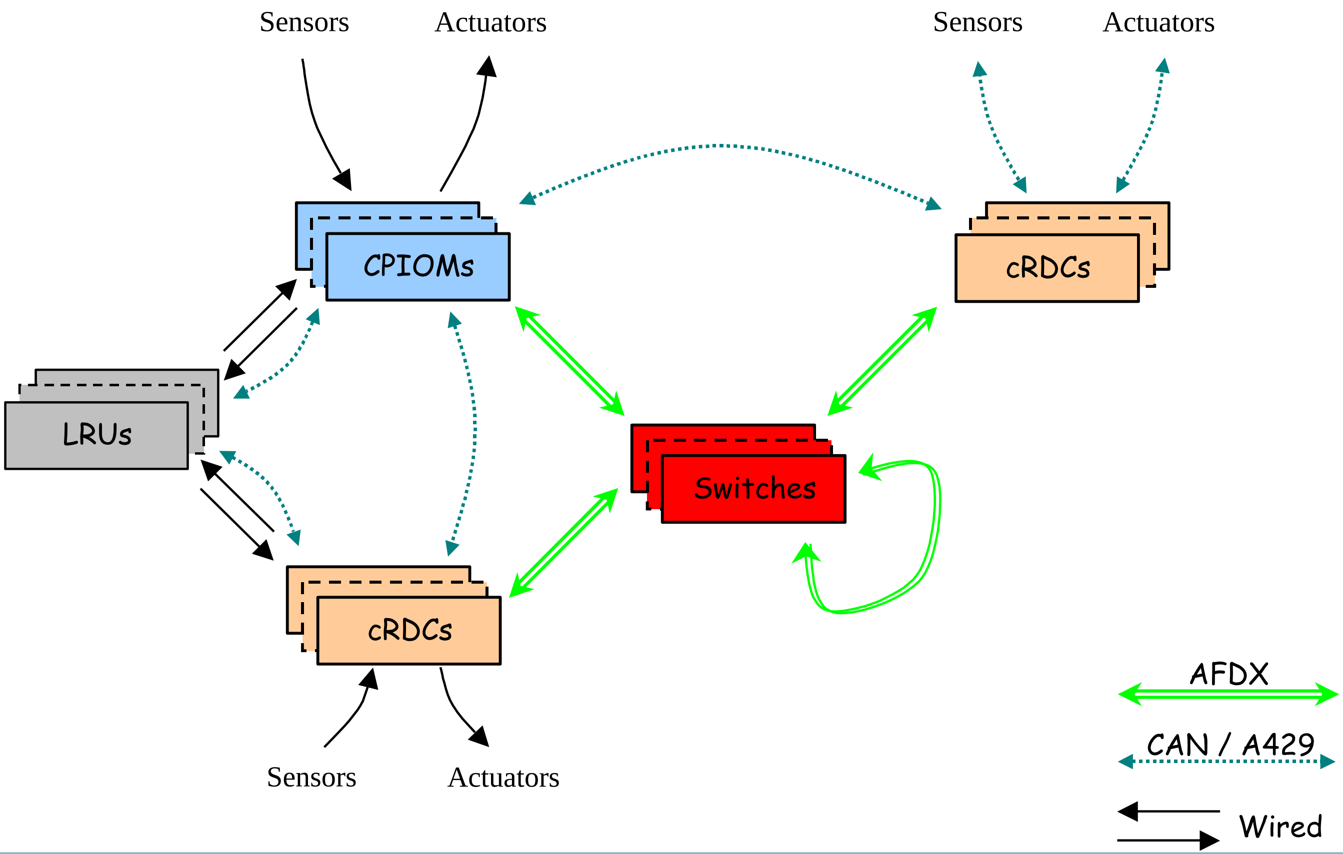


2-4 IMA Solutions, Modules & Tools

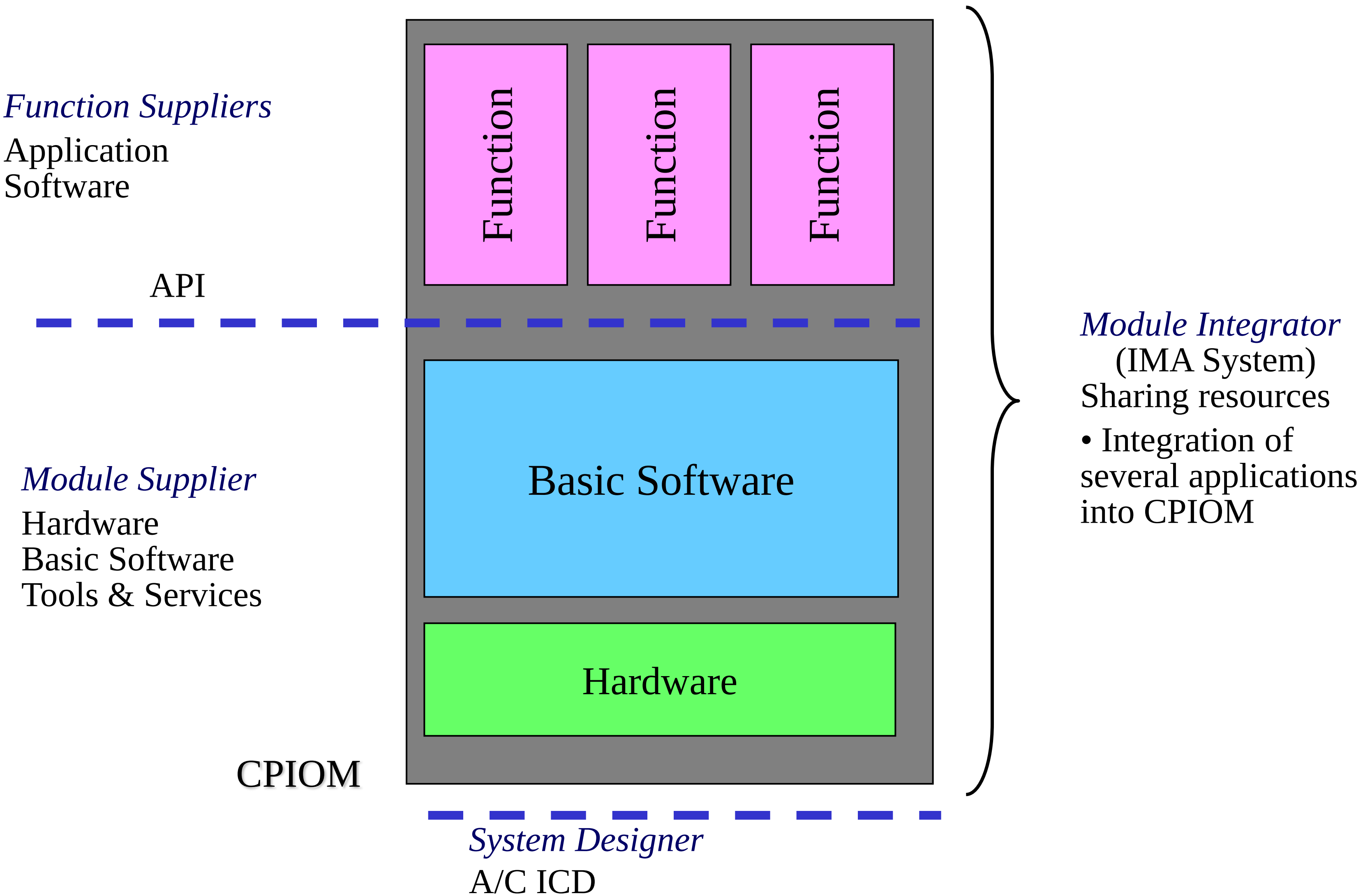
Example of avionics topology



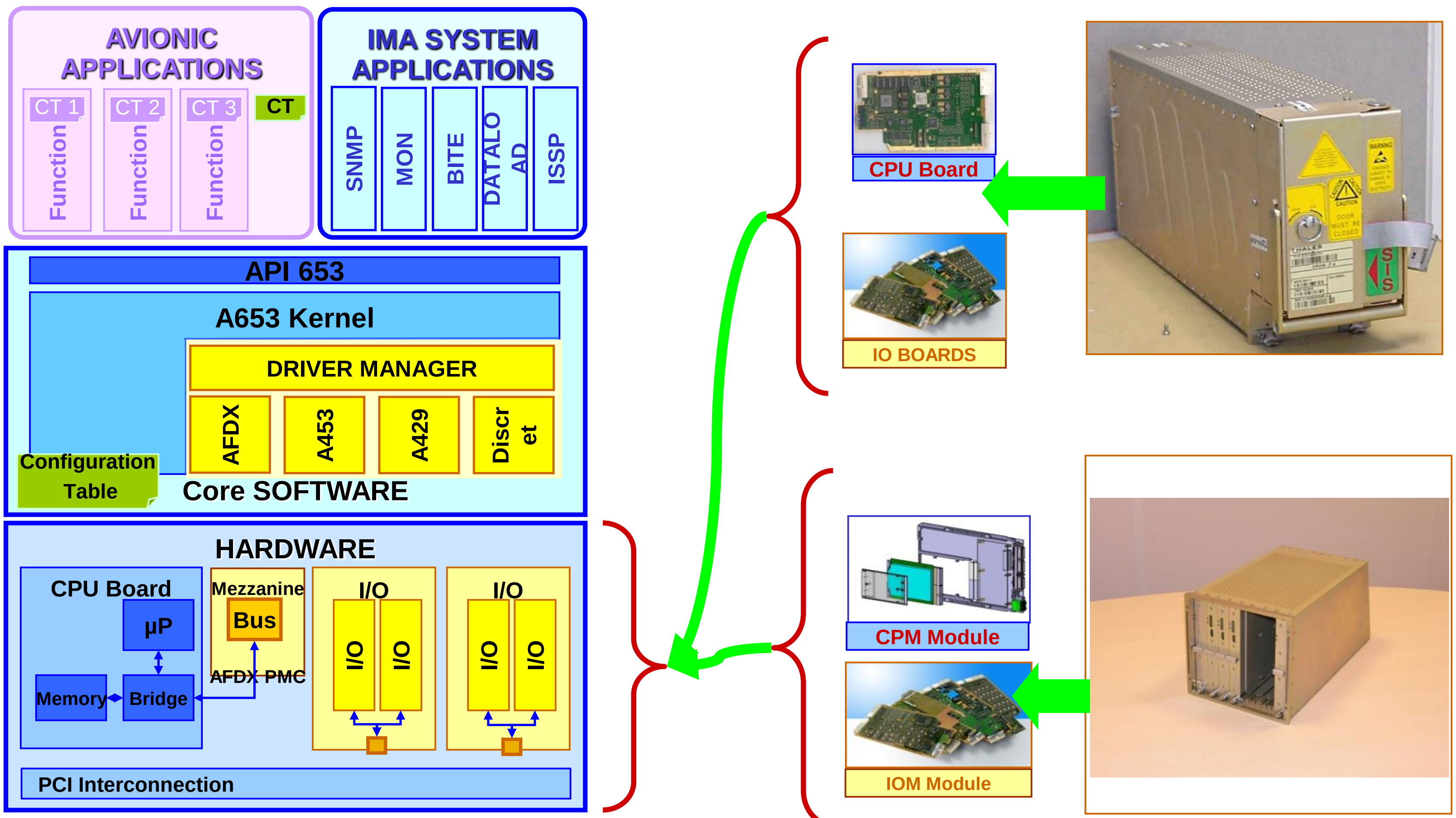
cRDC (Common Remote Data Controller)



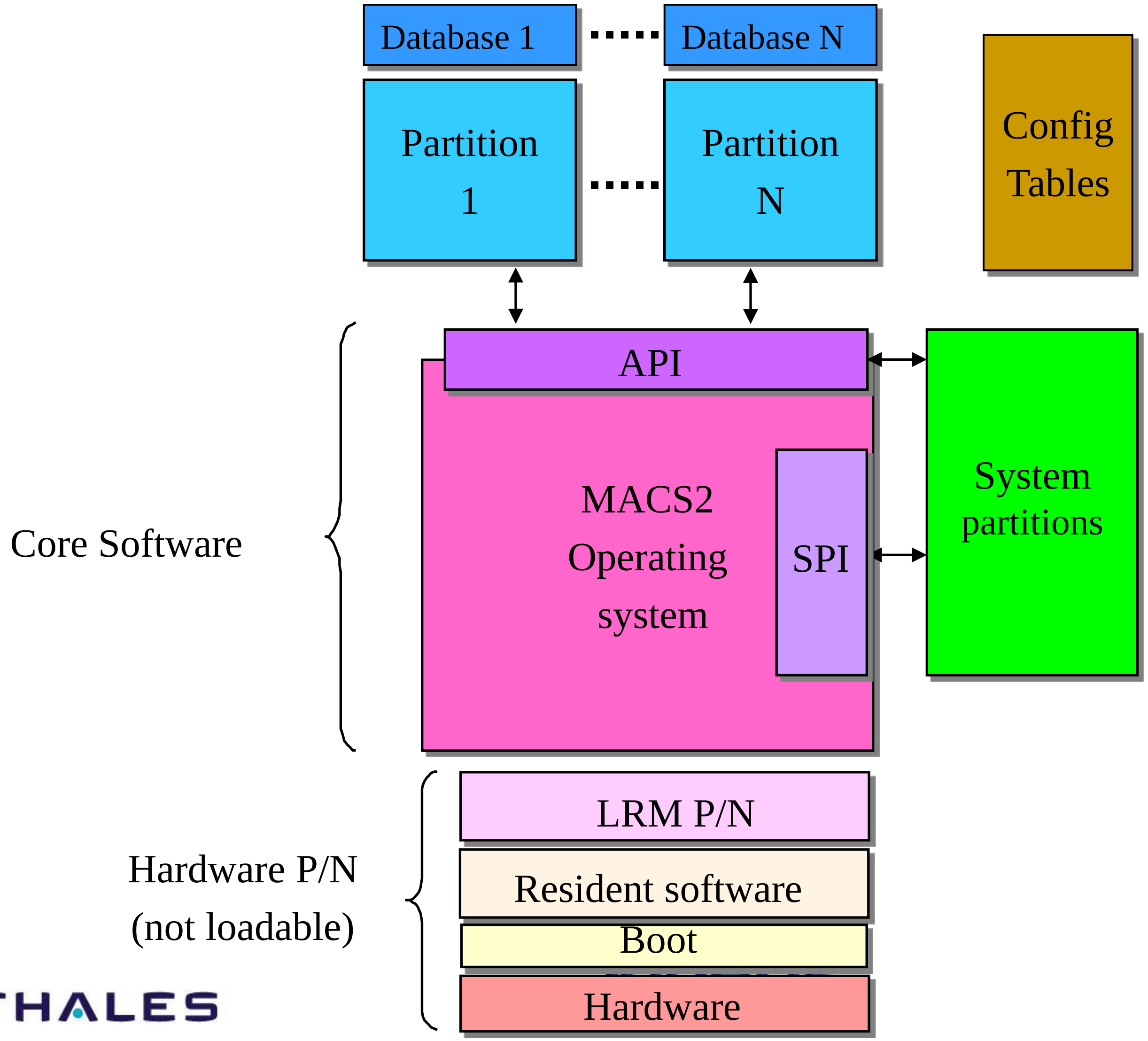
cRDC = common Remote Data Concentrator

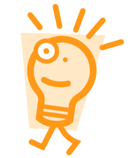

Function Suppliers
Application Software
API
Function
Function
Function
Module Integrator
(IMA System)
Sharing resources
• Integration of several applications into CPIOM
Module Supplier
Hardware
Basic Software
Tools & Services
Basic Software
Hardware
CPIOM
System Designer
A/C ICD

IMA Processing Module detailed breakdown



CPIOM Software Architecture (Example)





Partition

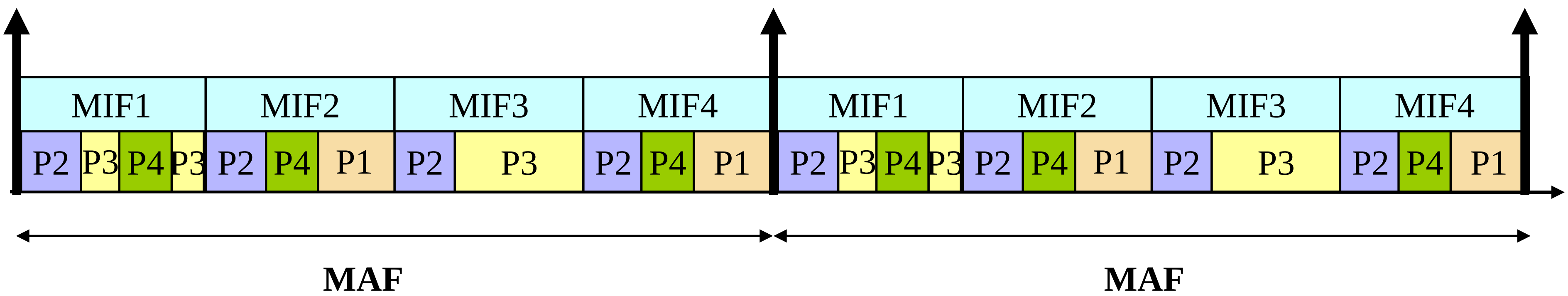
- Binding provided by Module Supplier (2 libraries)
  - API
  - MATH (optional)

- Partition = binary file made of :

  - Source code developed by Function Supplier in C language
    - It is made of
      - A start up sequence
      - A computation sequence
      - An error handler sequence
  - files from configuration tables

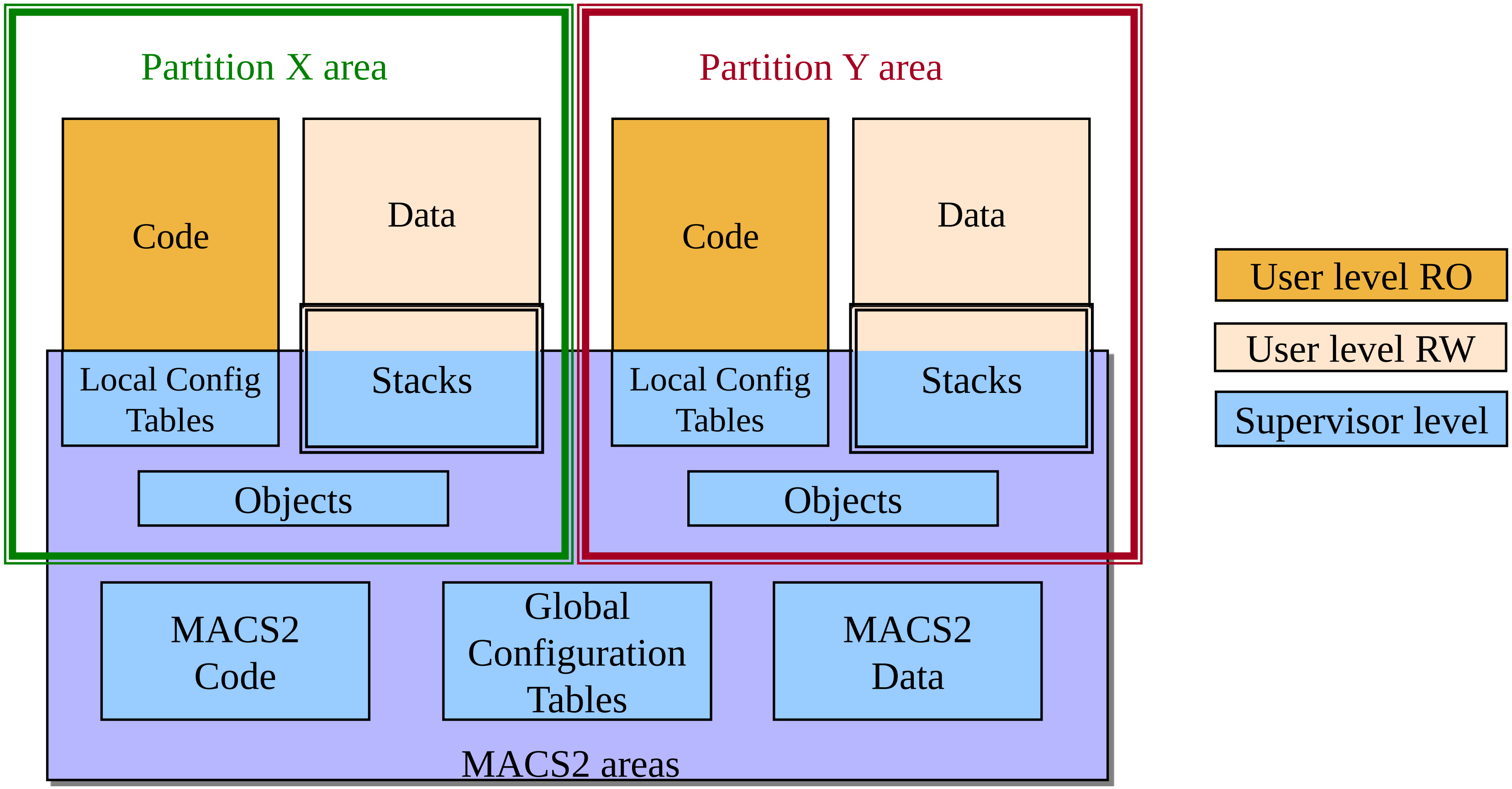
Partition = Segregated unit in time, memory and I/O

Time partitioning



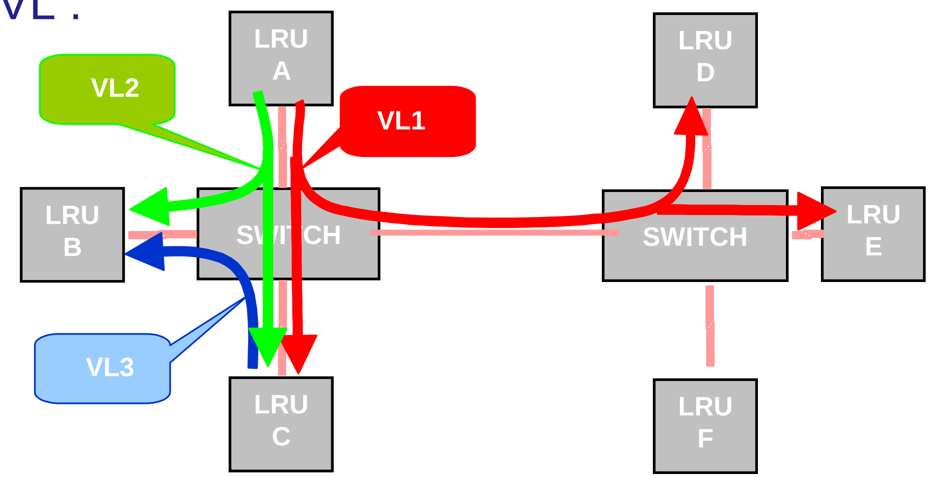
- Time allocated statically
- MAF = k * MIF
- P(n) duration = n * 100 µs (granularity)

Memory partitioning (RAM)



AFDX : Network partitioning

- A Virtual Link (VL) is a logical link between a single source and several destination equipments
- Quality of service is ensured for each VL :
  - Minimum bandwidth;
  - Maximum delay;
  - Maximum jitter (variation)
  - Static route;

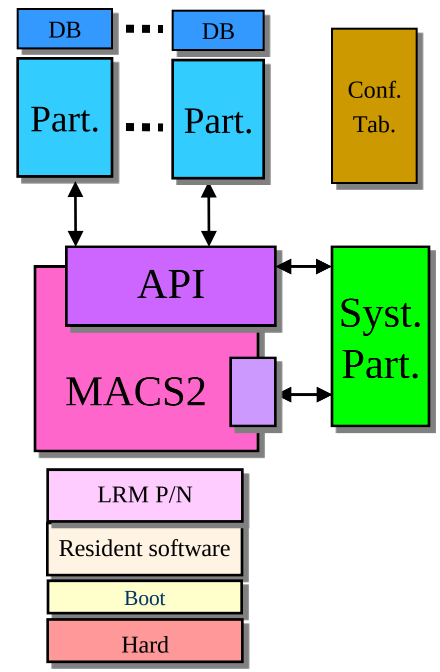


- This quality of service on a VL is ensured whatever the traffic on other VLs

One Virtual Link = partitioning

API

- API : Application Programming Interface
- Based on ARINC 653 standard
- Provides specification of services related to
  - Partitions
  - Processes
  - Time
  - Communications
  - NVM (Non Volatile Memory, e.g. for Logbooks)
  - Errors (configurable health monitoring)



Partition access relies on API services only

System partitions

- Perform management tasks which
  - Are common to several applications
  - Can not be performed by user partitions
- System partitions are:
  - RBITE (Faults report)
  - SNMP (AFDX failure detection)
  - MON (Monitoring of I/O – Engraving to NVM)
  - IS-DL (Instrumentation – Dataloading)
- Provided by Module Supplier in Core Software
- Configuration specified by Module Supplier

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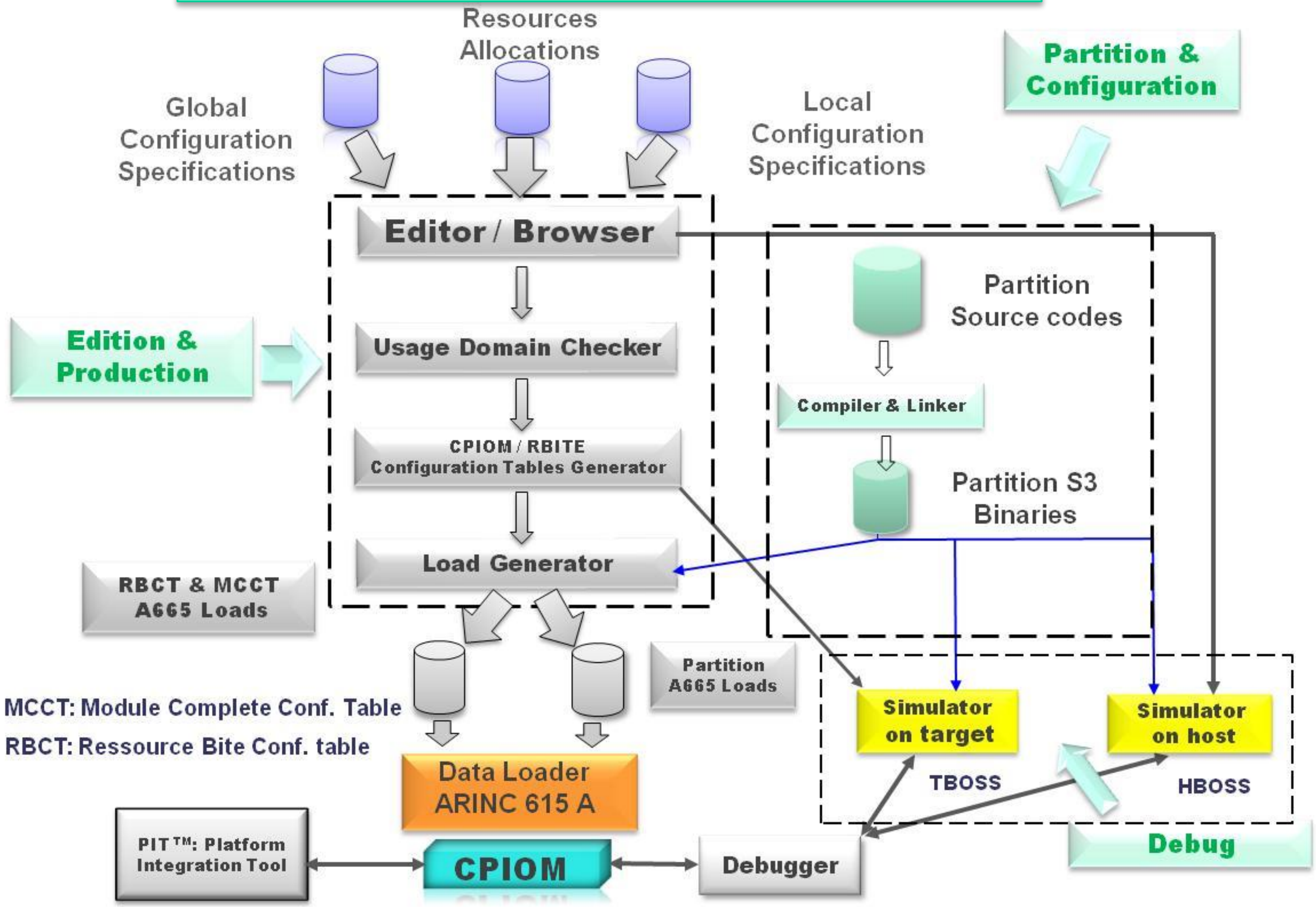
IMA CPIOM "Tool Chain" Production



2-5 IMA Certification Process Overview

Aircraft Certification

EASA

Aircraft

CRI/IP
Determination of Certification Basis

Regulations

CS-25/FAR-25

Certification Specifications for Large Aeroplanes

CS-25

Aircraft Certification Basis

CRI F-xx/IP S-xx

System

system

Standards

ARP4761
ARP4754

System "Qualification" Basis

Equipment

IMA
DO-297

HW
DO-254

SW
DO-178B

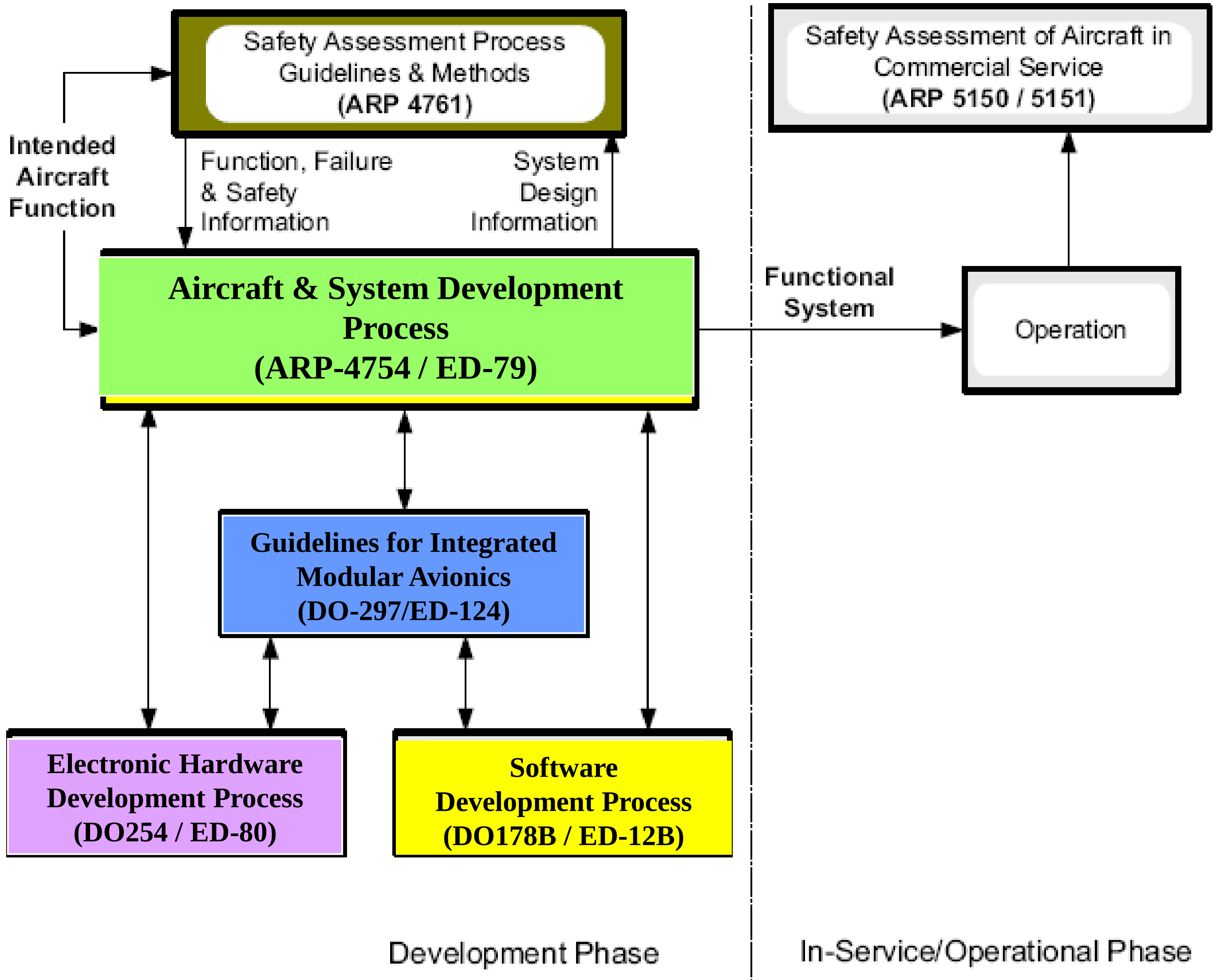
DESIGN ASSURANCE GUIDANCE FOR AIRBORNE ELECTRONIC HARDWARE

Environmental
DO-160

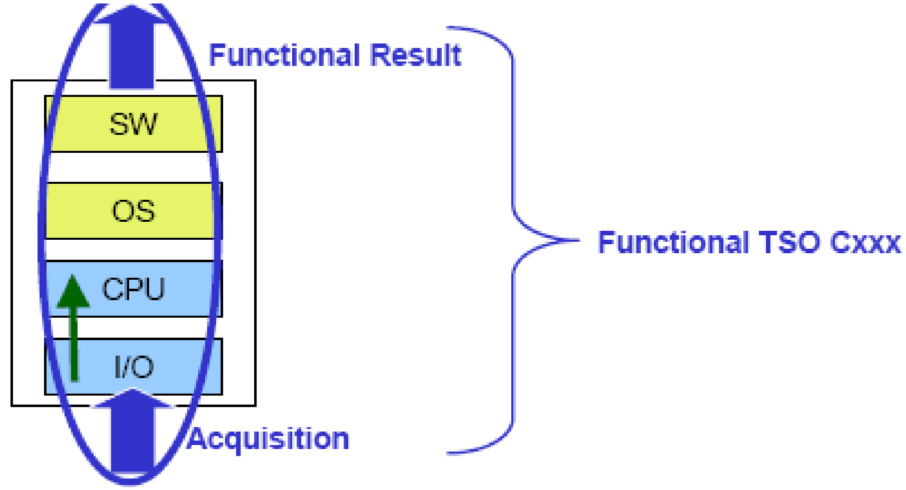
CRI F-xx/ IP S-xx

Equipment "Qualification" Basis

Links between Industrial Standards



Before : LRU approch

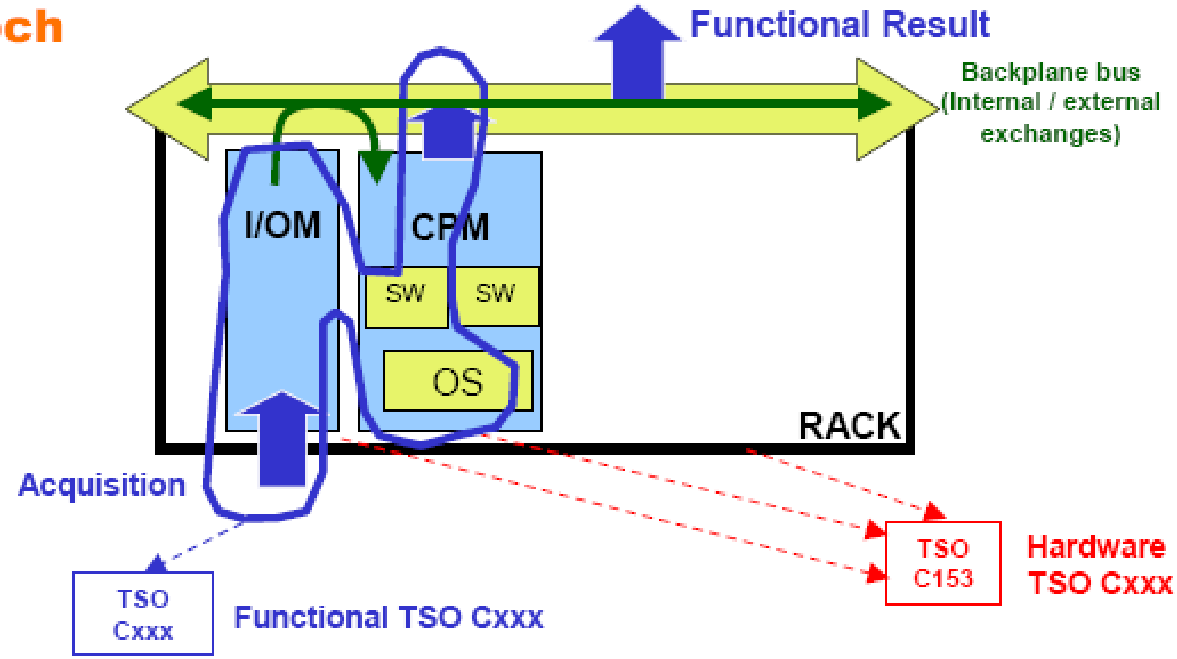


- Functional TSO Cxxx is (are) marked on the complete LRU (one P/N)
- LRU is composed of :
  - One hardware dedicated to the intended function(s)
  - One hosted software dedicated to the intended function(s)

Avionic System (AVS) was composed of LRU (HW/SW) supplying the intended function and MPS required into the TSO Cxxx

- Counter-parts :
  - Poor Avionic system architecture modularity.
  - Difficulty to adapt Avionic System to a new aircraft or inside an A/C family.
  - Difficulty to easy increase the dispatch (realiability may mean adding additional complete LRU for few I/O).
  - Difficulty to support rapid deployment of new features as they are certified.

Now : Modular approch



- Functional TSO Cxxx covers the functional chain and results
- IMA TSO C153 covers the hardware elements
- STC covers the validation of the intended function at A/C level

Avionic System (AVS) is composed of LRM defining an hardware backbone (open platform). The intended function and MPS required into the functional TSO Cxxx are isolated from the hardware

FAA / EASA systems

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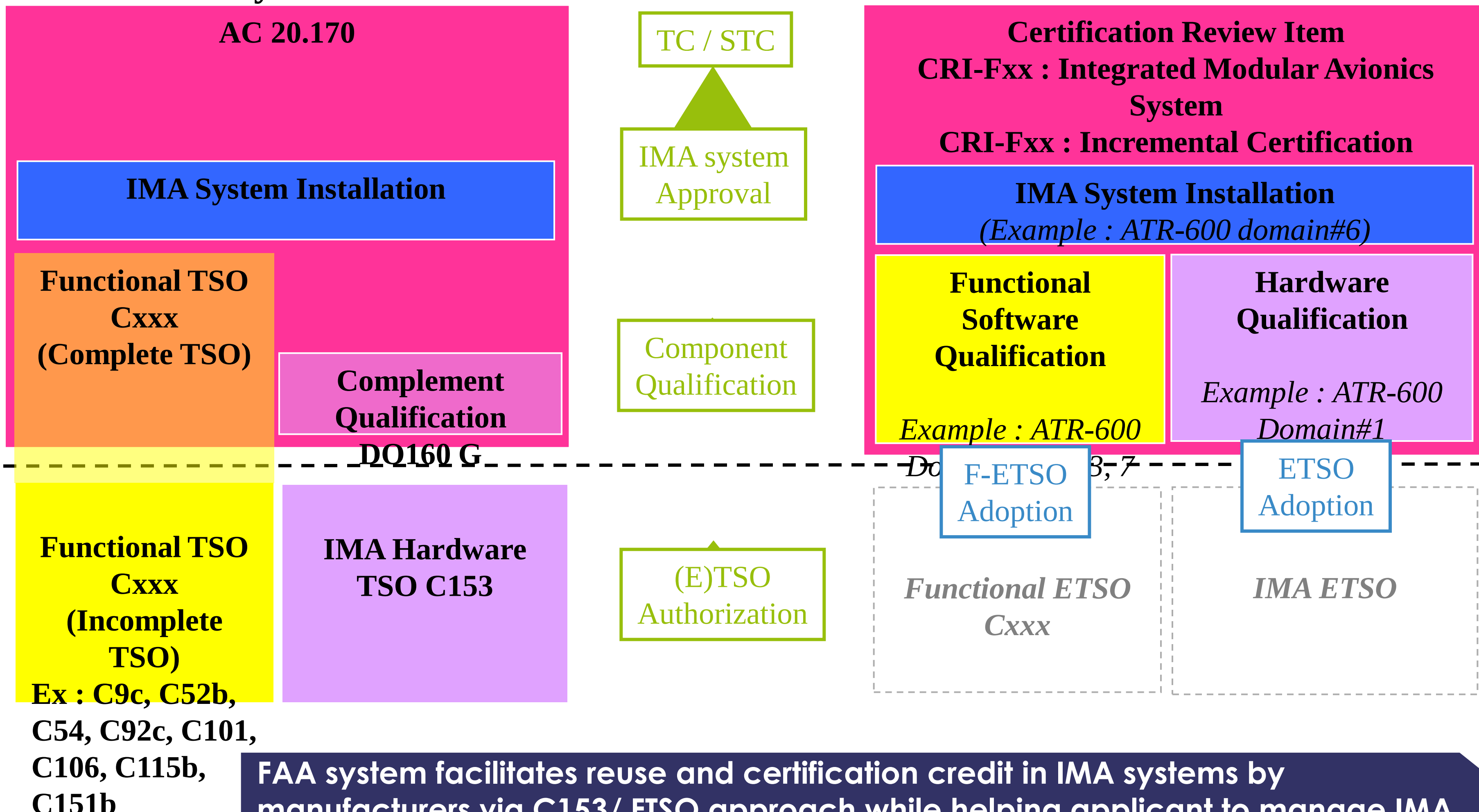
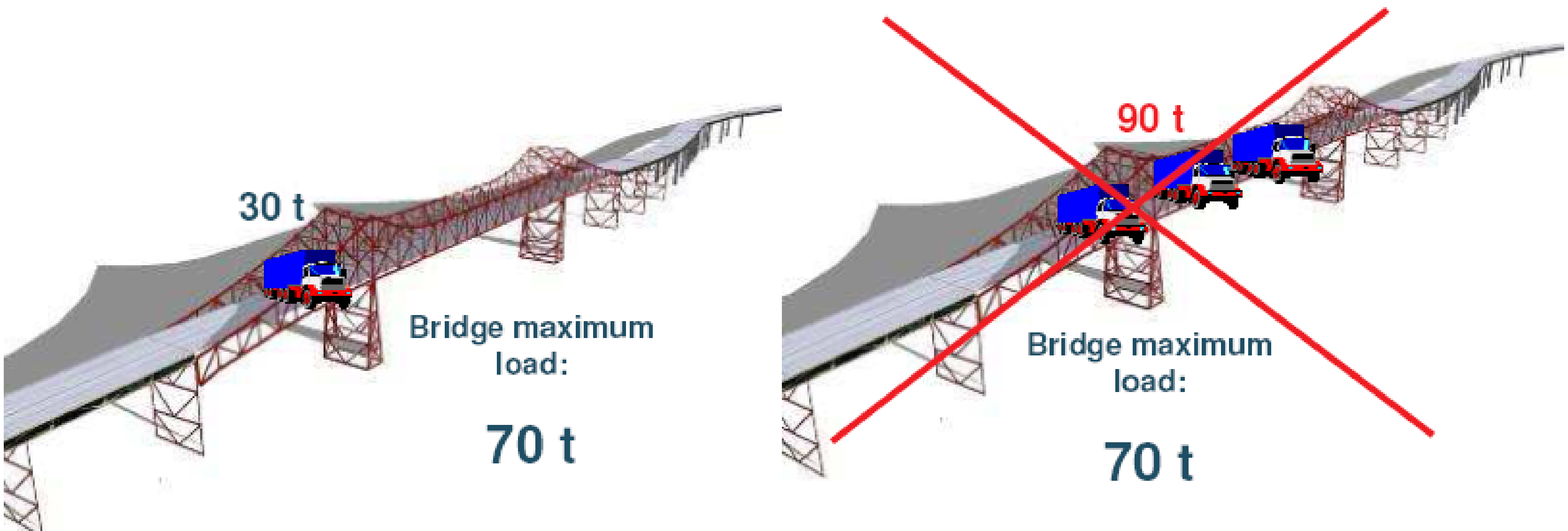
FAA system

EASA system



FAA system facilitates reuse and certification credit in IMA systems by manufacturers via C153/ FTSO approach while helping applicant to manage IMA system integration & install

- Cumulative Effect on loss or erroneous behavior of AFDX Switches or IMA Module has to be taken into account by a dedicated team
  - implies that the ATA 42 has its own safety analysis (FHA/PSSA/SSA)
  - implies that AFDX network and IMA is considered as a function (to justify the ATA42 FHA/PSSA/SSA)



Bridge = AFDX network and IMA modules
Trucks = Failure Conditions

2-6 Performances & Determinism

Processing : WCET Analysis

- 2 view points to be considered
  - **From the time partitioning viewpoint:**
    - Purpose is to verify that max atomic (non-interruptible) execution time of Operating System tasks or services are not likely to cause a slice out violation whatever the instant and condition of their call by partitions
    - A maximum figure for each contributive element is obtained by measurement or by analysis and computation when measurement cannot be performed
  - → Considered in the Platform qualification dossier
  - **From the Application Real Time and performance viewpoint:**
    - Purpose is to insure that applications running on CPIOM platform will meet their expected behavior and performances
    - whatever the execution time jitters they have to encounter due to their own variability domain as well as marginal jitters in their allocated execution time caused by precedent scheduled partition incursion in the slice out delay
    - provides to Applications developers some guidances (included in the User's guide).
  - → Considered in the Application qualification dossier and supported by Users Guide

WCET strategy

- **Strategy to manage WCET (Worst Case Execution Time)**
  - WCET determined by analysis
    - Analysis may be either manual, supported by tools or a mix of the 2
    - Analysis may be done on functional basis (Top / Down), on code (Bottom Up) or a mix of the 2
    - Analysis determines conditions in which WCET is obtained
    - Analysis determines corrections to apply
  - WCET value is obtained by measurement and ajustments
    - WCET is measured in the conditions
    - Measured value is ajusted by corrections determined by analysis
  - WCET determination supported by Users Guide:
    - Platform characterisation (OS execution times)
    - Recommendations to users

Network : Definition of determinism

- According to AFDX Standard ARINC 664, the ADN determinism is defined as :

- Assurance that the ADN does not change the frames sequence

- Compliance with the ADN feature capabilities (e.g. max allowable switch output buffer size = Usage Domain)

- Compliance with the user requirement on time spent for network transit (latency and jitter)

Network : WCTT Strategy

WCTT: Worst Case Transition Time

- Deterministic network design
- At End System level
- AT Switch level
- Monitoring insuring robust partitioning between Virtual Links

- Capability to compute end to end latencies using qualified algorithm
- Once budgets (Virtual Links) are defined according to constraints identified, Worst Case latency is guarantied

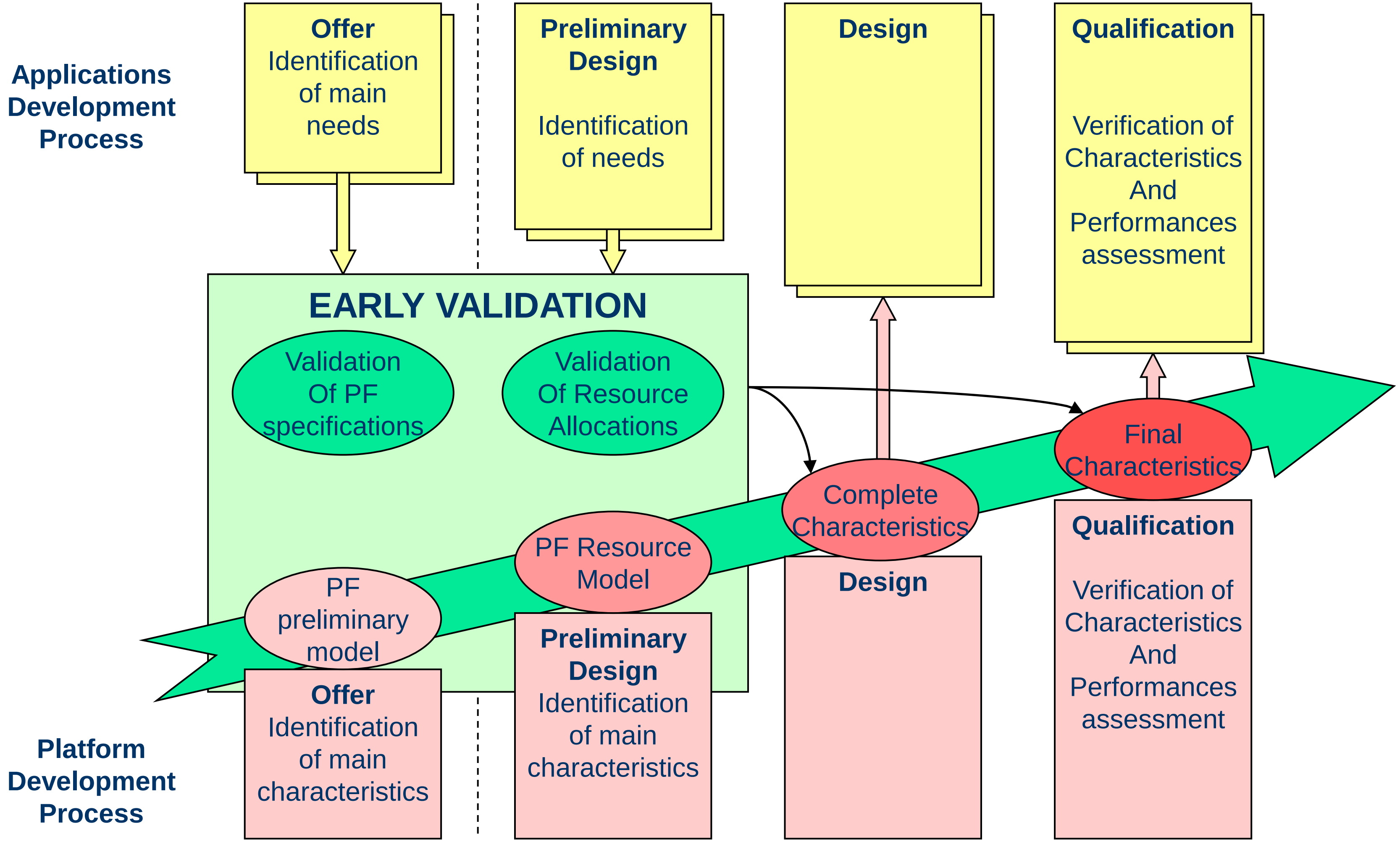
- Assessement is done between
- VL latencies formal specifications defined and validated from System needs
- VL worst case latencies computed using qualified tool

Example & Exercice to be performed during the N/W Session

Early Validation of Resource Allocation

- Objectives of Early Validation for resources allocation:
  - **Modelling of platform capacities and application needs**
    - Practicable in the early stages of development
    - Functional and high level
  - **Usage Domain rules verification for optimize partitioning**
    - Granularity of model compatible with final qualified usage rules
  - **Smart graphic approach: resource consumption status by domains**
    - Processor (Time & Memory)
    - Network (bandwidth & latencies)
    - I/Os (Sizing & Distribution)
    - Graphic
  - **Clear picture on spares:**
    - Local spare: permitting to each subscriber to evolve independently from others
    - Global spare: permitting to install new subscribers

Early Validation modelling positioning



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EVT Views