A380 Integrated Modular Avionics

The history, objectives and challenges of the deployment of IMA on A380
Presentation Topics and Scope

• To explain what IMA is and its background

• To explain how IMA has been deployed on the A380
  ‣ ADCN
  ‣ Modules

• The Future of IMA
Why IMA?

• Since the A300
  ‣ Increasing number of software controlled systems
    – New functionality for performance
      • Flight management systems
      • Fuel management systems
    – New functionality for improved safety
      • Flight envelope protection
      • Ground proximity warning
      • Traffic collision avoidance
    – New functionality for improved maintenance
      • Aircraft condition monitoring
    – New functionality for improved passenger comfort
      • Cabin environment control
Why IMA?

• The Indirect Consequences
  ▸ Every system = 1 or more computers / controllers
  ▸ Every aircraft type = new computers
  ▸ Every computer =
    – Airframer development and management costs
      • Part number costs
      • Documentation
      • More wires
      • More power
      • More sources of unreliability
      • Increased obsolescence risk
    – Airline impact
      • Spares
      • Tooling
      • Increased fault finding
Why IMA? – Traditional LRU

• This implies that quantities of maintenance spares be stored for each fleet at different places.
• During the aircraft life cycle, the cost of modifications, including parts obsolescence mitigation and functional upgrades, becomes even more significant for the airlines.
Why IMA? – Traditional LRU

- Each computer type is uniquely designed for the system and aircraft
  - Application software
    - e.g. fuel control
  - Hardware PCBs
  - Operating System
- Manufactured by system supplier
- Dedicated wiring for each connection
- 100s km cabling per aircraft
Why IMA?

Historical background for the emergence of IMA

Functionality (arbitrary log scale)

Number of electronic equipment

- Concorde
- A300B
- A310
- A320
- A330
- A340
- A380

A380 with IMA


10^5 10^4 10^3 10^2 10^1 10^0

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Why IMA?

• The response
  ‣ Integrated Modular Avionics
    – Concept
    – Not a specific set of technologies or components
  ‣ Integration =
    – Multiple systems applications executed on the same computer
    – Data communications integrated onto a high speed multiplexed network
  ‣ Modularity =
    – A set of standard non system specific computers
    – Computers that can be configured to provide part of their resources to a particular system application
What is IMA?

• IMA Variations / Proprietary Solutions?
    ‣ Avionics network
      – ARINC 429
      – ARINC 629
      – AFDX
    ‣ Avionics computers
      – Cabinet of modules, backplane, gateways
        • Honeywell AIMS
      – Cabinet of cards
        • Honeywell Primus EPIC
      – Independent modules as LRUs
        • Honeywell VIA
What is IMA?

• Cabinet of modules

• Functionality split between modules:
  ▶ Power Supply Modules, Gateways, Processing, IO

• Inter module communications backplane

• ARINC 653 Operating System

• Originally ARINC 629

• Single supplier …. for everything

• Boeing 777
What is IMA?

- Card File

- Semi open architecture – third party hardware
- Processing, IO and gateway cards
- Proprietary DEOS Operating System
- Proprietary backplane
- Business and Regional Jets
  - Embraer, Raytheon, Dornier
What is IMA?

• Independent Modules as “LRU”

• Derivative of AIMS – repackaging
  ▸ Provides processing, IO and PSU in one package
What is A380 IMA?

- Since mid 80s the former Airbus partners have done research on IMA for their systems (PACTS, IDEE3, NEVADA, PAMELA, VICTORIA)
  - With the objective to merge different system design approaches and different procurement approaches
    - Closed loop control systems, data management and processing systems
    - Safety critical and non safety critical
    - Software only functions to full multi-domain systems like fuel
    - Complete design in house, integration of components to fully outsourced

Therefore the IMA solution had to:
- Be suitable for different types of systems (I/O needs / Performances / Safety)
- Be suitable for a large number of systems and their suppliers to allow real competition
- Compartmentalised to allow parallel developments to be managed
What is A380 IMA?

Integrated Modular Avionics

« Federated architectures »

LRU « black box »

display

actuators

sensors

A629

Multi-transmitter bus network

CABINET

LRU

AFDX NETWORK

MODULE

CONCEPTS & TECHNOLOGIES EVOLUTIONS
What is A380 IMA? - Airbus Concept

- IMA shared resources are:
  - the avionics communications network: the solution selected is AFDX (Avionics Full Duplex Ethernet), fully compatible with Ethernet network of Open World and based on common switch modules
  - Modules, i.e. Core Processing & Input / Output Modules or CPIOM, Input/ Output Modules or IOM, ...) for hosting of several applications and signal acquisition/transmission
What is A380 IMA? Airbus Concept

• The AIRBUS IMA concept is based on “shared Modules”. A module-focused approach has been preferred compared with the previous concept of “Cabinet”. Its key features are:
  ‣ ARINC 600 IMA Module packaging connected to AFDX network
  ‣ Robust partitioning in computing resource & communications
  ‣ Determinism of application execution & data exchanges
  ‣ Standardised Application Programming Interface (API) to avoid obsolescence impacts on applications
  ‣ Conventional equipment’s mixable

• Resource sharing has a direct impact on the way to design and implement systems since it creates new dependencies between them, both from a technical and a process point of view.

• This concept has been selected as the baseline for systems design on Cockpit, Utility, Energy and Cabin domains and extended globally on all the domains.
AFDX Network:
- 100 Mbits
- Redundant Network (A&B) with independent alimentation
- AFDX switches = 2 x 8
- NB of ports (connections) possible on each switch (20-24)
- MTBF of the switch is very high (100 000 hours expected)
- Up 80 AFDX subscriber
AFDX - Generality

- Freedom of choice for data format (harmonized at aircraft level)
- Integration of LRU, IOM (Input Output Module) & CPIOM (Core Processing Input Output Module)
- Technology based on COTS standards

- Switching table defined through configuration
- Traffic policing (enforcement of allocated bandwidth)

- ARINC 600: 2 MCU
- QUADRAAX Connectors
Avionics communications are based on multicast:
  - one transmitter
  - one or several receivers

- Asynchrony individual clocks
- NO reconfiguration capability in the AFDX network
AFDX: Performances

• Does AFDX sustain expected real time performance:
  ‣ Yes: real time performances were really challenging, both on the ES and the switch (ES wire speed reception ie 200 Mbits/s ; switch wire speed switching, with only bottleneck on output buffer).

• Packet loss percentage:
  ‣ 0 % in the switch by definition (a configuration where the switch cannot guarantee that no frames are lost is not “schedulable” and thus not produced)
  ‣ Nevertheless frame may be lost due to
    – Bit error rate (target 10-8)
    – Failures
What is A380 IMA? - AFDX Network use

- **Switches Configuration process:**

  - System Team
  - Data base
  - NCD: VL & Paths
  - Confcheck → determinism OK
  - Confgen → Create configuration Loads
  - Switches Datalaoding
What is A380 IMA?

• Impact on the system development process = Risks
  ▸ At the component level:
    – IMA developed before system > requirements mismatch
    – Maturity of IMA components > impacts multiple systems
    – Technical capability > impacts multiple systems
  ▸ At the Industrial level:
    – Management > Dedicated trans-national IMA team
    – Procurement >
      • Arbitration process,
      • Contractual resources,
      • Change in supplier business model
    – Development > User Groups, Hot Lines, Bi-laterals
    – Certification
    – Support Process > Airbus
What is A380 IMA?

• Pre launch
  ‣ Partner activity to review available solutions and proposals
    ‣ Many suppliers example Smiths, Honeywell, Rockwell Collins, Thales, Diehl, BAe Systems
    ‣ Front runner - Cabinet / rack + ARINC 629

• Joint launch team to define the avionics solution
  ‣ Architecture, scope, key technologies, supplier pre-selection
  ‣ AFDX as the network
    ‣ ARINC 629 future growth, cost ?
  ‣ IMA computers as dedicated LRUs – The “Open Architecture” solution
    ‣ Multiple system suppliers
    ‣ Scalable
    ‣ Multiple IMA suppliers including Airbus make policy for key technology
    ‣ System suppliers able to develop and integrate separately
    ‣ Minimise the management and co-ordination activities to be performed by Airbus – focus on systems
What is A380 IMA? - IMA integration perimeter

Cockpit

Cabin
Bleed, Overheat Detection, Supplemental Cooling, Cabin Pressure & Ventilation Control, Air Conditioning

Utility
Fuel Measurement & Management, Braking, Steering, Extension/Retraction, Others (Tyre pressure, etc.)

Energy
Electrical Load Management, Circuit Breaker Monitoring, ATA 24 BITE

Function on A380
IMA – Modules

- 8 different part numbers / 30 modules of CPIOM per chipset developed by 2 suppliers
  - **AIRBUS (EYY):**
  - **Thales Avionics**, associated with Diehl Avionik System:

- They host 21 avionics functions developed by 10 suppliers

- 1 single part number of IOM called “IOM-A”

- All modules are ARINC600, 3 MCU box, around 4.2 kg, with 50 000 hours MTBF objectives
What is A380 IMA?

• What makes IMA different?
  ‣ Standardised Software Environment
  ‣ ARINC 653 Operating System
    – Application software is independent from the hardware
      • Like Windows
      • No direct access to I/O
      • Internal process control services
      • Health Monitoring services
    – Enables Obsolescence protection for system software
      • Software – largest NRC element of systems
      • Production life = 20 years, Aircraft life = 50 years
What is A380 IMA? - CPIOM

CPU Board

- RAM
- Flash
- NVM
- DSI / DSO
- AFDX
- PCI
- CPU MPC755
- Partitioning Control
- Intra LRM Communication

Power Supply

- Interface
- USB
- DSI / DSO /DGO

IO_DSP Board

- Interface
- AUDIO
- Flash
- DSI/DSO
- DGI

AVIONIC PARTITION

A 653 Operating System

Drivers

Boot

BASIC SOFTWARE

AIRBUS API

AIRBUS API + Extensions

PowerSupply

DSP TMS320C33 + internal Ram

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What is A380 IMA?

• What makes IMA different?
  ‣ Partitioning
    – The performance of each system must be unaffected by any other
      • To allow systems to be developed, tested and verified separately
      • To allow system faults to be contained
      • To allow new systems to be added post certification
What is A380 IMA?

- What makes IMA different?
  - Partitioning
What is A380 IMA?

• What makes IMA different?
  ‣ Partitioning
    ‣ Timing
      • Strict allocation to each system application –
        ‣ Periodic fixed scheduling at application level
        ‣ No prioritisation at application level
What is A380 IMA?

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What is A380 IMA?

• What makes IMA different?
  ‣ Partitioning
    – Timing
      • Strict allocation to each system application –
        ‣ Periodic fixed scheduling at application level
        ‣ No prioritisation at application level
      • Overruns are prevented partition is suspended
What is A380 IMA?

- What makes IMA different?
  - Partitioning
    - Memory
      - Segregated allocation to each application
      - Configuration is linked to design i.e. application accesses only the memory configured for it
      - Violations detected and prevented by MMU
What is A380 IMA?

- What makes IMA different?
  - Partitioning
    - I/O
      - Segregated allocation to each system application
      - Some shared input data e.g. ARINC 429
      - All access is through OS calls
What is A380 IMA?

• Partitioning enables:
  ‣ System independence
    – Systems of different DAL(A,B,C) level can be developed at their DAL level
    – Systems can be integrated and tested to separately
  ‣ Incremental Qualification
    – Modifications to one application have no effect on other applications
      • Qualification activities following a modification are limited

• Configuration Parameters Partitioning and Configuration
  ‣ IMA must be configurable
    – Resources – Time, Memory and I/O
    – Implemented with Configuration Tables - loadable
  ‣ Two groups of tables:
    – Tables managed by Airbus – have a global effect
    – Tables managed by the Function Supplier – only have a local partition
What is A380 IMA?

- Qualification of the module within a usage domain represented by the set of configuration parameter ranges
- Usage Domain
  - Represents guarantees on
    • Functionality
    • Performance – e.g. service call times
  - For the range of configurations the module can be used in
What is A380 IMA? - IMA Modules Qualification

- Qualification and system certification are major parts of IMA
  - The objective of the qualification approach is to give System Suppliers “credit” to be used as part of their system certification
  - Based on credit
    - The function / system supplier takes “credit” from the qualification activities of Module Manager and Module Supplier
    - Does not have to prove functionality, performance and behaviour of the module.
What is A380 IMA?

• New Industrial Roles - the biggest change with IMA
  ‣ Introduce a new role in system development
    – IMA Manager
      • Control the use of module resources
        ‣ Provides resources against user system requirements
        ‣ Maintain spares margins
        ‣ Support the prediction and verification of resources
      • Provide resource configuration tables
        ‣ Develop configuration tables
      • Perform confidence testing on the Integrated Module
      • Perform qualification activities for the module configuration
What is A380 IMA? - Avionics Functions

• Integration:

  ‣ integration tests are performed
    – on HBOSS
    – again on HBOSS with instrumented code for structural coverage analysis
    – then on TBOSS for target compatibility verification and for providing certification evidences
  ‣ Additional unit tests may be identified to achieve all coverage objectives
  ‣ The whole process is automated to ease non-regression testing between HBOSS and TBOSS
The future
The future of IMA

• A380 IMA reused on A400M/A350:
  ‣ Mature avionics hardware available immediately
  ‣ NRCs, risks minimised

• Next Aircraft – IMA2G:
  ‣ Extend the scope of IMA
    – Flight controls, Open world
  ‣ Increase the flexibility of IMA – “Generic Secure Platform”
    – Optimise the IMA architecture
      • Decentralised I/O / Smart sensors
      • Reconfiguration
    – Enable more systems to be integrated within IMA
      • High Critical to Low Critical
    – Enable greater levels of integration on single IMA units
The future of IMA

• Change in technologies:
  ‣ AFDX:
    – greater bandwidth solutions,
    – low cost solutions
    – greater integration
    – All protocols supported
  ‣ IMA
    – Cabinet, Card File? all have advantages
    – Faster processors – Multi-processor – inevitable
    – New OS – possibly, parallel for Open World
    – New Fields buses technologies?

  ‣ Tools - greater integration & Industrialisation
    • Platform Architecture definition
    • Avionics configuration
    • Application development, validation and verification
    • Fast ramp up – Technologies choice for Resources industrialisation
    • Fast FAL Integration – Auto test
The future of IMA

Historical background for the emergence of IMA

Functionality (arbitrary log scale)

Number of electronic equipment

Concorde 1970
A300B 1975
A310 1980
A320 1985
A330 1990
A340-600 1995
A380 2000
Future A/C with IMA 2005

Future A/C

A380 with IMA

A340-600

A330

A320

A310

A300B

Concorde
Thank you for your attention