Evolution of Integrated Modular Architectures: Cross-Industry Perspective

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Why Integrated Architectures?

Integrated Modular Architectures: Rely on Advanced System Integration

- Optimized functions lead to reduced lifecycle costs
- Aerospace industry has the edge in design of integrated systems, ...
- … but the volumes are low and the capability to influence component ecosystem is limited
- Therefore cross-industry developments cannot be neglected!
IMA: System Integration

Boeing 777 AIMS (1994)
- IMA with Safebus (A659)
- 60 MBit/s (bus)

Airbus A380 (2006)
- IMA with Ethernet (AFDX)
- 100 MBit/s (star)

Airbus A350
- Domain-based „Distributed“ IMA
- Common Core Systems (CCS) / RDC

Boeing 787
- Optimized Domain-based „Distributed“ IMA

Special Avionics/Defense-Only Networks
- Ethernet with Deterministic Services / Network Deployment

Synchronous MoCC
„Distributed IMA“ DO-297

Asynchronous MoCC
„Complex IMA“ DO-297
Pre-Ethernet IMA Architectures

- High-Bandwidth Databus ARINC659 and ARINC629 (supported computing models: TTA, L-TTA)
- ARINC653 not invented in 1993 (Honeywell’s DeOS uses time-partitioning)
- Falls into „Distributed IMA“ category (see DO-297)

Initial approach to tight integration, using the baseline technology available in early 1990s

- IMA B777: limited CCR
  - The communication is based on TDMA bandwidth partitioning and time-controlled medium access strategy
  - The level of integration limited by computing and networking capability
What is Distributed IMA (RTCA DO-297)?

**DO-297 Definition**
- Fault-tolerant system with a set of computing resources accessing the TDMA partitioned network
- TDMA Backplane / Backbone Network
- Example D.2 in DO-297, p.121.

**Differences vs IMA**
- Complex IMA (D.4):
  - **Baseline Technologies:** ARINC653(time-partitioning RTOS)+ ARINC664(robustly partitioned asynch. Eth.)
  - Distributed IMA covers all (legacy) integrated (sub)systems with robust TDMA partitioning
  - Boeing 777 IMA(1993), Honeywell PRIMUS EPIC, Boeing 787 Power Generation Controls...

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**Figure D-2: Distributed modular platform**

Purpose of this example
This architecture example illustrates how a fault-tolerant, distributed platform for real-time applications can be established based on robust partitioning of the communication network resource. Based on a strict TDMA (Time Division Multiple Access) pattern the communication platform provides robust partitioning either between LRUs (on a sub-system bus, distributed throughout the aircraft) or between LRM (on a backplane bus, within a cabinet). The platform is designed to provide a robustly partitioned communication service to hosted applications, even in the event of a single, arbitrary software or hardware fault within any of the applications or the communication network itself.

The platform allows for the assembly of an application-specific, fault-tolerant network from a set of standard, configurable hardware boards (top-level, combined HW/SW modules of the platform) linked using a partitioned fault-tolerant digital communication network as shown in Figure D-2.
IMA: System Integration

Modern architectures rely on commercial and automotive networks (Ethernet + CAN), plus legacy ARINC429 networks.

- Boeing 777 AIMS (1994)
- Airbus A350
- Boeing 787

IMA with Safebus (A659)
IMA with Ethernet (AFDX) Backbone
Domain-based „Distributed“ IMA
Common Core Systems (CCS) / RDC

60 MBit/s (bus)
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Synchronous MoCC „Distributed IMA“ DO-297
Asynchronous MoCC „Complex IMA“ DO-297
What is Distributed IMA? How this relates to Ethernet?

Evolutionary Considerations

- Ethernet cannot (could not) do TDMA partitioning before 2006
- Since 2006 - it can! (SAE AS6802 and related IEEE standards)

Key Difference: Network Resource Partitioning and Supported Computing Models

- **Distributed IMA (SAE AS6802):**
  - Ethernet: Time-partitioning at network layer with per-flow timing/VL policing (*Synchronous VLs*)
  - Ethernet-based variant supports TTA and L-TTA MoCC (Models of Computation/Communication), open and closed systems

- **Complex IMA (ARINC664):**
  - Ethernet: Statistical multiplexing with per-flow/VL policing (*Asynchronous VLs*)
  - Supports L-TTA MoCC, closed systems only!
IMA Architectures: Complex IMA (DO-297)

ARINC664 + ARINC653 (L-TTA)

Equivalent technology baseline, but different architectures.

- **CCS IMA B7xx:**
  CCR + RDC

  More generic and theoretically more scalable IMA, for different systems

- **Domain-based distributed IMA A3xx:**
  CPIOM + cRDC

  Designed for larger aircraft with predefined functional domains
Space Avionics/IMA: NASA Orion

Complexity similar to Airbus A380 IMA:

- Convergence of mission controls, multimedia, hard RT, real-time and soft-time…
- „Complex IMA“ and „Distributed IMA“ (DO-297)


Successful First NASA Orion Test Flight With TTTech’s TTEthernet On Board

TTTech supports the design of the NASA Orion Onboard Data Network (ODN) and advanced integrated system architectures for human-rated space flight based on TTTech’s TTEthernet technology and products
Convergence in Ethernet-Based IMA: New Capabilities

**Asynchronous VL (Complex IMA)**
- **ARINC664**
  - Supports L-TTA
  - Real-Time Performance
  - Closed Systems (predefined critical and non-critical function performance)

**Synchronous VL (Complex/Distributed IMA)**
- **SAE AS6802**
  - Supports TTA and L-TTA
  - Enables "Embedded Cloud"
  - System-Wide Hard RT Performance due to fixed latency (SW function separated from controlled object)
  - Open Systems (predefined critical function performance, arbitrary non-critical performance)

Complementary capabilities available in Deterministic Ethernet Switches!!!
Distributed/Complex IMA Demonstrator
ARINC664/SAE AS6802

- 12 x TTESwitch A664 Lab 24 ports
- 18 x TTEEnd System A664 Lab
- 18 x CES RIO6-8093 SBCs
- 18 x TTECOM Layer for VxWorks 653
- 6 x CES ARINC 429 Cards
- 1 x TTETools V4.3 (incl. A615 Data Loader)
Technology / Application Areas: Deterministic Ethernet

Safety / Availability / Performance

Low/Medium  High

Applications

CROSS-INDUSTRY:
Time-Sensitive / Time-Critical / Fail-Stop

AEROSPACE:
Time-Critical / Safety-Crit. / Fail-Operational

IEC 61508
ISO 26262
ARP4754/DO-297
DO-178/254
Deterministic Ethernet Markets in 2020-2025

~230Mio. Ethernet Ports/Year in 2020

Can you see aerospace here??

- Automotive
- Industrial
- Energy
- Railway
- Aerospace
- Space
Fail-Stop and Fail-Operational Requirements

Strong trend towards fail-operational

Fail-Operational

Design assurance standards are similar across industries

IEC 61508
ISO 26262
DO 178 / 254
EN/ISO 13849
Automotive Systems

Cost-sensitive, high-volume applications (i.e. capability to influence component ecosystem, MCU, networks, …)

Since 2011

• New Safety Regulations
• Advanced Integration
• Sensor Fusion
• Autonomous Driving
Audi’s zFAS – High-Performance ECU

zFAS, co-developed with TTTech, enabling Audi to integrate a variety of innovative functions with multiple safety criticality levels. zFAS uses numerous technology components from TTTech. For example, the individual CPU cores are connected based on Deterministic Ethernet communication.

“ Our goal is leadership in piloted parking and piloted driving. For this purpose TTTTech and Audi are developing a highly advanced high-performance central electronic control unit. ”

Ricky Hudi, Head of Electronics, AUDI AG
Renesas and TTTech Pave the Way to Highly Automated Drive

Joint development of a new automotive platform solution - providing a future proof, high-performance advanced electronic control unit (ECU) development platform for driver assistance systems (ADAS)

Watch “Renesas and TTTech pave the way to Highly Automated Drive” on YouTube

https://youtu.be/PSle3jO6bgE
New Integrated Automotive Architectures using Deterministic Ethernet

Beyond 2020: Domain Master Gateways

- Higher part commonality
- Integration of all domains via deterministic Ethernet
- ADAS: Safety- and time-critical systems via Ethernet
- Similar to domain-based IMA, but requires Distributed IMA capabilities

Automotive industry ecosystem after 2020-2025

- Ethernet Backbone with 3-6 switches
- SoC and MCUs with Deterministic Ethernet
- Integrated System Applications
- Safety-relevant distributed applications
- Support different models of computation/comm.
The Automation Pyramid: Soon to be Ancient History?

- Rigid infrastructure with separation between levels of functionality
- Levels connected by dedicated, specialist networks
- Data exchange only via gateways or proprietary systems
- Difficulties to access data transparently at the cyber pyramid (machine) level
Flexible Factory Automation and IoT Infrastructure

- Flat Architecture: Logical machine / control boundaries are dissolved
- Deterministic Ethernet-based platforms supporting L-TTA and TTA
- MIXED CRITICALITY: Real-time and non-real-time domains integrated

- In aerospace context: Mixing „Distributed IMA“ and „Complex IMA“-type of architecture from DO-297
Factory Integration: RT Virtualization for Common Computing Resources

**Fog Computing**
for advanced integrated systems

- Deterministic Networking
- Real-Time Controls And Safety
- Real-time data aggregation and event distribution
- Data analytics and visualization
- Health Monitoring and Predictive Maintenance

Joint Investments With KUKA in Solutions for Industry 4.0
KUKA and TTTech announce a strategic cooperation for joint investments in real-time technology platforms and start-ups to implement Industry 4.0 solutions even more quickly, starting with an investment in a Silicon Valley start-up focussing on real-time cloud computing.
Ethernet-based Integrated Railway Architectures

Deterministic Ethernet to enable new integrated railway architecture

SAMPLE IMAGE from MITRAC
Cross-Industry Needs vs. IMA

- Cross-industry applications will require both “Distributed IMA“ and “Complex IMA“ (DO-297 terminology) networking and architectural capabilities to support:
  - Ethernet as a converged network!
  - Support for L-TTA and TTA models of computation and communication
  - Hard RT and mixed criticality distributed functions
    - Audio/video, multimedia, real-time controls, safety functions and alarms, health monitoring, reconfigurability
  - Truly modular integration and certification
  - … similar to next generation IMA
Summary (I)

• ARINC664 and SAE AS6802 will be the preferred solution for aerospace industry in long term (in terms of maturity, certification, network capabilities, architecture investments and installed base)

• High volume embedded industry ecosystems evolve to support safety-critical SoC, and deterministic network

• In the longer term (>8-10 years), the cross-industry ecosystems and related products may be mature enough to support the capabilities required for critical applications and advanced integrated architectures
Summary (II)

• TTTech works on networks and embedded platforms for cross-industry applications with key semiconductor companies, targeting critical integrated infrastructure.
Summary (III)

• In aerospace domain, TTTech focuses on AFDX/ARINC664, SAE AS6802 and compliance with future cross-industry Ethernet developments for optimized next-gen IMA platforms.
Rugged AFDX® / TTEthernet Switches for Hard Real-Time Data Communication

The AFDX and TTEthernet Switches are rugged, ultra-light weight, conduction cooled, out-of-the-box high-performance Ethernet switches designed to meet the challenges of the harshest environments.

Find out more

Certifiable Gbit AFDX / TTEthernet Switch for Hard Real-Time Data Communication

TTEthernet Switch A684 A600 Pro is a high-speed, certifiable deterministic Ethernet switch enabling critical network-centric applications in harsh aerospace environments. An AFDX switch variant is also available.

Find out more