Avionics Synchronous Deterministic Backbone

A Network Technology for the Next Generation of Military Avionics

Summary and Value Proposition

Avionics Synchronous Deterministic Backbone (ASDB) is an emerging open System Area Network technology, that has been under consensus-based development by multiple partners in the German Avionics industry since 2020. The technology has been fully validated, and to a large extent been demonstrated using prototype hardware and software in a relevant environment.

Key aspects and motivators are:

- solution driven by end-user provided needs and expectations (customer perspective) & independent from business interests of individual actors
- open systems approach with supply chain autonomy
  - open technology and tooling without vendor lock-in
  - low barrier of market entry for suppliers in the avionics industry
- meets next generation military IMA data network backbone requirements (use cases, functions, performance, safety & security) at minimized complexity
- low complexity reduces time to market and total cost of ownership
- suitable to support integrations across manned or unmanned, fixed or rotary wing aircraft
- standardization by open industry body
  - DIN NA 131-04-09 AA „Avionik“, and potentially CEN[1]/ASD-STAN[2] D2/WG9
  - enables German-national / European sovereign solutions

What is it technically?

A deterministic backbone-type data network **designed for modular avionics platform applications** within an aircraft at all levels of integrity.

Another standard? – Why is it even needed?

Existing and emerging avionics network technologies based on profiled variants of Ethernet (including IEEE802.1DP / TSN[3] for Aerospace, AS6802A / Time-Triggered Ethernet, ARINC-664P7 / AFDX[4], ARINC-664P7A / AFDX-2G) imply one or more of the following:

- **High complexity** even after extensive profiling
- Narrow solution space for topology, link layer (incl. bandwidth, latency) and data path redundancy
- Vendor and/or integrator-specific abstraction, tooling and/or extension layers are required to enable network configuration, management and transparent use for operational purposes

ASDB presents its **value proposition** standalone or in augmentation to above or other technologies by:

- Focus on relevant core capabilities at very high efficiency and **minimized complexity**
- Leverage of existing and proven technical concepts into a **novel but low-risk solution**
- Enabling true **simplicity** in network usage for communication participants
- **Scalability** for different performance levels and integration cases
- **Interoperability** & ease of augmentation with other protocols
- Open standard includes **avionics grade specifications & open-source tooling** for configuration, validation & deployment

[1] CEN: European committee for standardization
[2] ASD-STAN: European standardization organization for aerospace and defence
[3] TSN: Time Sensitive Networking
[4] AFDX: Avionics Full-Duplex Switched Ethernet

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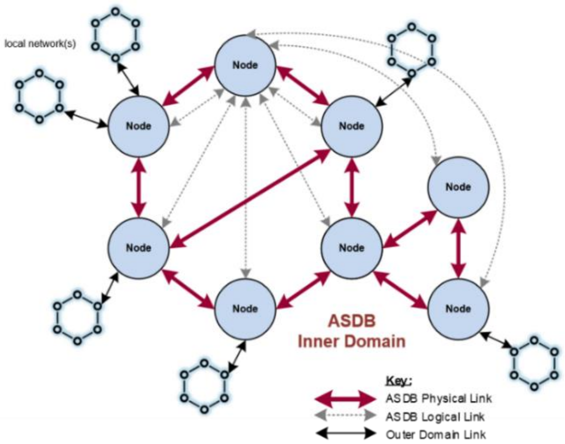
Key Technical and Performance Characteristics

Conceptual & Performance

- pre-engineered network approach
  simplifies determinism analysis with all communication paths and their characteristics known at integration time
- built upon subsets and proven concepts from public standards
  including IEEE 802.3 (physical link layer) and ARINC 664 Part 7 (Virtual Links)
- designed as a backbone type network
  light-weight native communication structures and deterministic bridging of higher-level protocols
- logical point-to-point full mesh on **integrator defined physical topology**
  tailored to integration-specific availability and reliability objectives
- bandwidth seamlessly scalable with **integrator defined open link layer technology**
  e.g., 100 Gbps+ per link on optical fiber technology viable for military avionics
- common **low hop latency**
  e.g., <300ns on optical fiber technology viable for military avionics
- supports the usage and interoperability of contemporary and legacy protocols
  including Ethernet, TSN, AFDX, MIL-STD-1553, ARINC 429, ARINC 818, discrete signals, and others
- **remote memory transfer** optimized for inter-process communication (IPC) and remote IO applications
  with dedicated pre-processing for legacy bus protocols



Representative ASDB integration use case:
Integrator-defined hybrid ring/mesh physical topology (red) between ASDB nodes providing backbone network access and logical point-to-point connectivity (dashed gray) between arbitrary outer domain users & interfaces (black)

Safety, Security & Dependability

- designed for **deterministic communication**
  in contrast to constraining/profiling non-deterministic aspects of commercial technologies that were made for a different context, e.g. the internet
- traffic shaping via strict Time Division Multiple Access (TDMA)
  enabling hard determinism across all communication channels, with jitter bound by precision of the time synchronization
- no need for traffic priorities
  transmission rights implicitly defined with the network schedule for deterministic and arbitrated best effort type allocations, within deterministic bounds
- unique robust and resource-efficient **time synchronization at ns-precision**
- tailored combination of open-standard integrity mechanisms
  facilitates link level guaranteed transmission, increases link reliability, and simplifies error handling
- **avoidance of central switches** & complex software in the network infrastructure
  single type of nodes enables more efficient certification up to DAL- A
- Hardware-enforced **safety and security partitioning**
  enabling mixed criticality and multiple levels of security as a service by the network subsystem
- **very high resilience** to failing elements
  no dependency on central elements, any combination of functional and interconnected nodes remains interoperable
- optional multi-redundant data paths, managed by the network not the user
  hardware-managed arrays of virtual links mapped to physically independent routes, and/or networks

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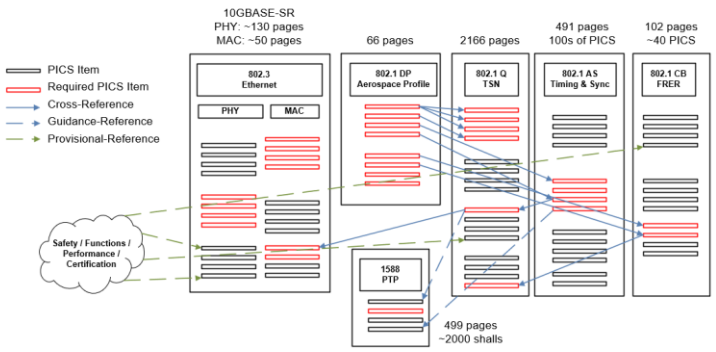
Complexity – Why it matters

Especially in aerospace applications, **total cost of ownership** of a solution directly scales with technological complexity of its elements. And this cost is paid by an integrator, either in form of up-front investment, or across the life cycle, directly or indirectly. In addition, there is a need for an aggressive time to market as well as fast and cost-efficient re-configuration to enable system upgrades during the lifecycle of the aircraft.

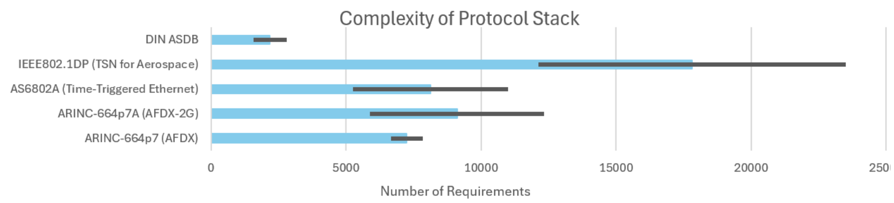
To compare total cost of ownership, contributions from multiple independent experts in the global avionics industry have enabled a scientific evaluation of current and near-future avionics data network technologies with respect to solution complexity. The evaluation was part of research in German national consortia on NGWS IMA and ASDB development at DIN NA 131-04-09 AA „Avionik“. The study included ARINC-664p7 (AFDX), ARINC-664p7A (AFDX-2G), IEEE 802.1DP (TSN Ethernet for Aerospace), SAE AS6802 (Time-Triggered Ethernet) and DIN ASDB. Comparison metrics based on generic IMA platform requirements for a data network have been assessed qualitatively (process efforts to establish adequate objective evidence for use in avionics) and quantitatively (number of requirements needed to fully specify a system solution). The study simulated typical avionics development and integration cycles for a data network infrastructure based on a common set of requirements that can be met with acceptable compliance by either technology option. A structured development process as per aerospace standard objectives was applied, with decomposition starting at equipment system level, down to component level (Line Replaceable Unit → High Level Requirements → Low Level Requirements). For established technologies, multiple independent data points have been extracted from development actuals for fielded products.

Evaluation Results show a wide range of projected effort required to specify, build, integrate and maintain avionics data network integrations for different technologies. The figures below indicate the specification document dependencies for IEEE 802.1DP (TSN for Aerospace) and the estimated number of requirements for the evaluated technologies.



Qualitative Results example: Complexity of TSN for Aerospace Specification Sets with scales and interdependencies of individual specification documents. Similar situation for other profiled Ethernet variants.

Quantitative Results: Estimated number of requirements expected, with ASDB numbers significantly below the other evaluated data network technologies.



With ASDB, **life cycle costs** can remain significantly lower than with other data network technologies due to its focus on core functionality at lowest complexity.

Time to market directly relates to complexity, because a solution fully characterized with fewer requirements is usually implemented and tested faster.

Its scalability for different **performance** levels and integration cases enables tailored and optimized solutions for integrators, owners and users alike.

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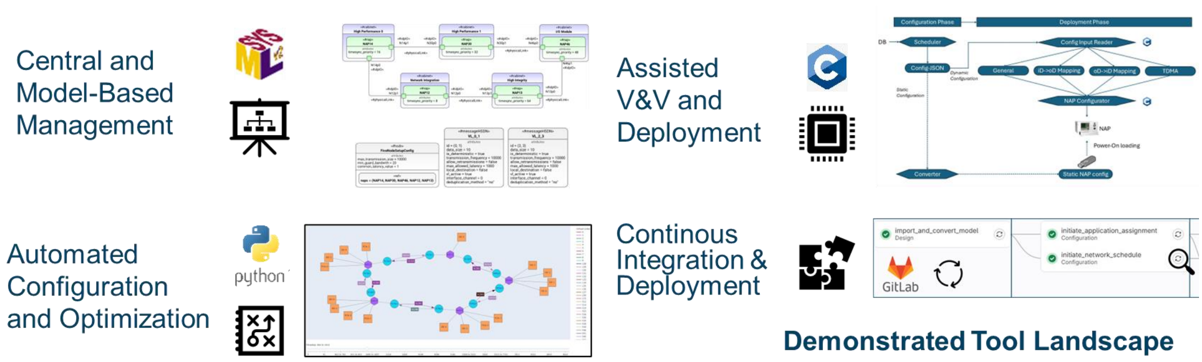
System Design Ecosystem and Tooling Landscape

Current network design and configuration challenges are driven by increasing complexity and the need to enable rapid updates. In addition, comprehensive and **automated tool support is necessary** to manage complexity and allow timely and certifiable configuration of the avionics networks. To tackle these challenges, a network technology has to be openly available and fit into the ecosystem of modern avionics developments. Unfortunately, **tool landscapes** for other network technologies such as TSN and AFDX are currently **fragmented and vendor-specific**.

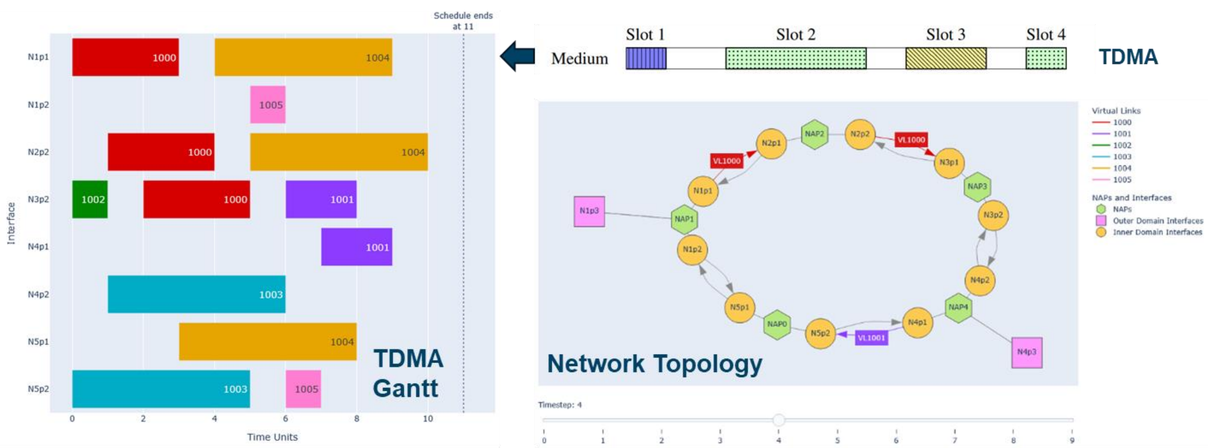


Demonstrated Tool Landscape

ASDB addresses these **ecosystem and tooling needs** with a defined integration path into modern Model-Based Systems Engineering (MBSE) developments and available **open-source tooling**. Prior work showed how ASDB networks can be:

- **Designed and managed** with modern and model-based approaches
- **Configured automatically** with optimization algorithms (open-source[5])
- **Visualized interactively** Gantt and network topology diagrams (open-source[5])
- **Verified and validated** against predefined network requirements (open-source[5])
- **Updated rapidly** with Continuous Integration/Deployment (CI/CD) workflows

Automatically Generated Visualizations of Optimized TDMA Schedule



Schedule per Interface

Interactive View of Network Utilization

[5] https://github.com/DLR-FT/ASDB-scheduler

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Proof of Concept Implementation and Performance Evaluation

Multiple iterative development steps were performed, maturing the key aspects of the ASDB core specification. As a representative link layer selection, the proof of concept implementation used a link layer specification for 100Gbps inner domain links on multi-mode fiber media aligned with off-the-shelf assets. Even though this implementation provided a prototype demonstration in a relevant environment (avionics system integration lab), it is considered TRL 5 because not all ASDB network access point functions were demonstrated.

ASDB Network Access Point Hardware and Software

The ASDB network access point (NAP) was developed as a modular function block with hardware and software items and was integrated into multiple different LRUs.

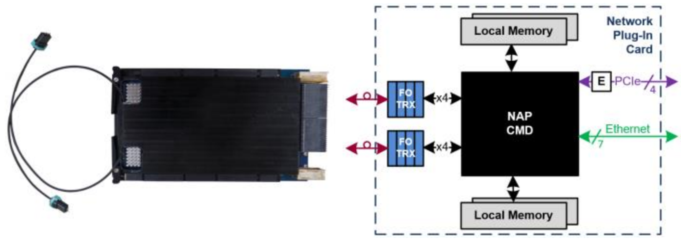


Photo and Block Diagram of the NAP proof of concept hardware asset.

NAP hardware:

- COTS 3U OpenVPX Plug-In Card with FPGA
- 2x 100 Gbps inner domain interfaces per link and direction on multi-mode fiber baseline
- Shared ASDB Network Access Point function with Ethernet & PCIe outer domain interfaces
- Inner domain with integrity protection and link layer replay capability
- Time synchronization with around 100ns precision, 300ns hop latency
- Ethernet encapsulation/bridging and PCIe based Inter-Process Communication (IPC)

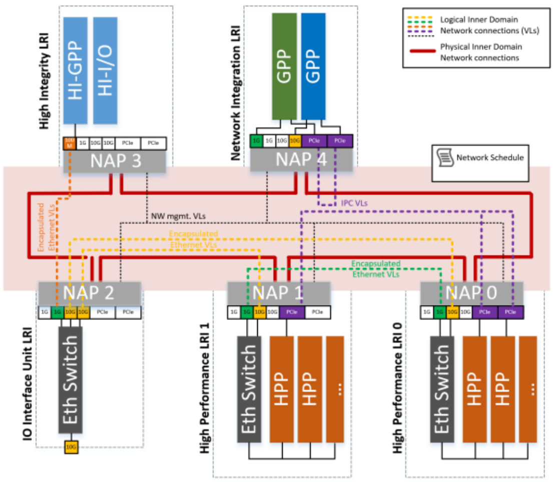
NAP software:

- Reference drivers and integration tools for Linux on x86 High-Performance General Purpose Processors (GPPs) and real-time operating systems on High Assurance GPPs

ASDB as Data Network Infrastructure in an IMA Platform Demonstration

Demonstrated data network capabilities

- Segregated data network communication between processing entities
- Network time synchronization & determinism
- Network extension/bridging (Ethernet) and memory-mapped (host-to-host IPC) communication
- Network management
- Redundant network data paths
- Two types of network nodes: Processing Subsystem & Interface Unit
- Basic data concentrator function: Remote Ethernet IO
- Mixed integrity, safety & security support
- Tool-generated network configuration



Current and future integration steps: Additional avionics IO, video & sensor data distribution and control flow authenticity.

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