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TIME-SENSITIVE NETWORKING FOR AEROSPACE

EVOLUTION OF ONBOARD NETWORKS

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FOUNDATIONAL TECHNOLOGIES

TSN Time-Sensitive Networking Powered by IEEE 802

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RECAP – TSN WEBINAR SERIES

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- The Impact of Time-Sensitive Networks - An Introduction to IEEE 802.1
- Driving Digital Transformation through IEEE 802.1 TSN - An Overview of Time-Sensitive Networking
- The Transport and Impact of Synchronization in Time-Sensitive Networking - An Introduction to IEEE 802.1AS
- IEEE 802.1 TSN Webinar: Audio/Video Bridging
- TSN to the Fore of the Transition to 5G with IEEE 802.1CM™
- IEC/IEEE 60802TM: The Case for the Converged Network in the Factory of the Future
- IEEE P802.1DG: Evolving the In-Vehicle Network from Audio/Video Bridging (AVB) to TSN

Speaker – Abdul Jabbar

Principal Engineer, GE Aerospace Research

Dr. Abdul Jabbar is a Principal Engineer at GE Aerospace Research, where he leads the research, development, and adoption of next-gen networking technologies for aerospace applications. In previous roles, he delivered communication solutions for Transportation, Healthcare, Power Generation, and Homeland Security. He is the editor and co-chair of the joint IEEE/SAE standard on the TSN profile for Aerospace. He holds Ph.D. and M.S. degrees in electrical engineering from the University of Kansas, US.

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TSN for Aerospace: Motivation

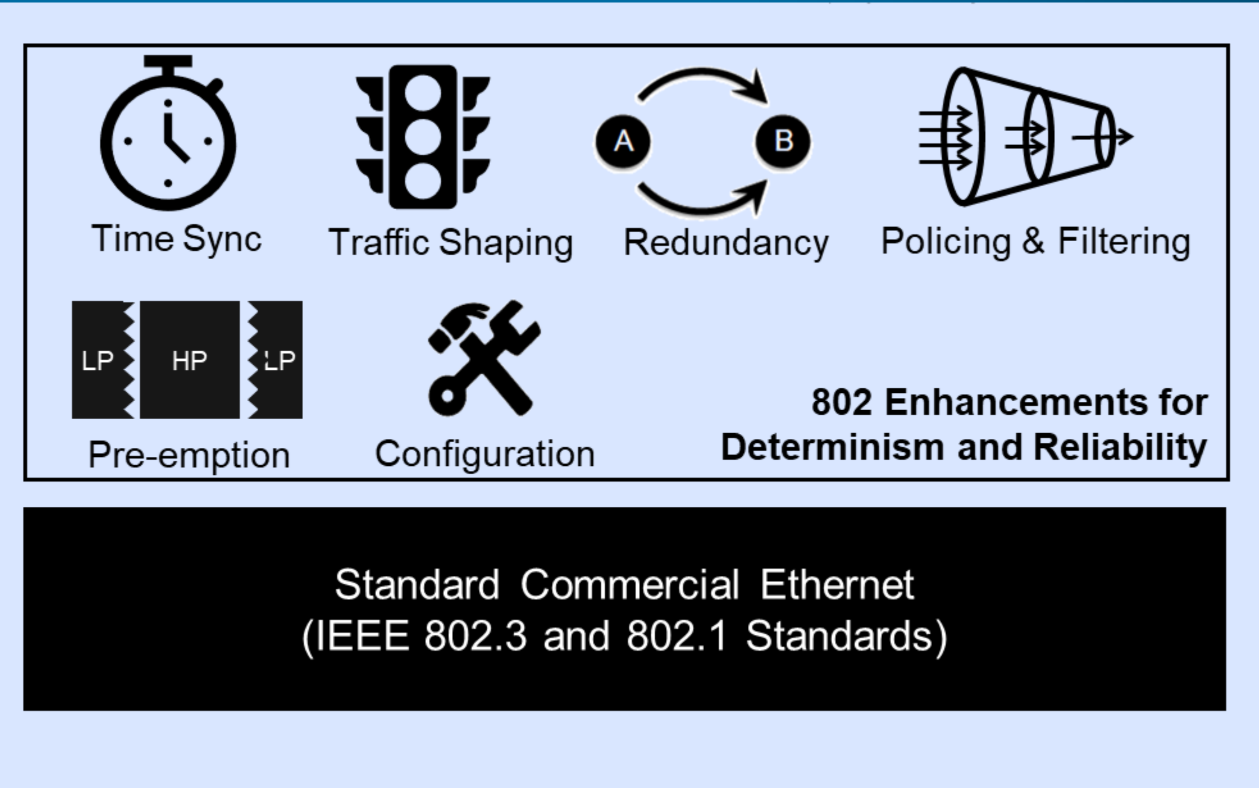
Evolution of Aerospace Onboard Networks

Standard	Standard Evolution	Max Data Rate
MIL-STD-1553 (Serial)	1973-1978	1 Mbps
ARINC 429 (Serial)	1977	100 Kbps
IEEE 1394 (Firewire)	1994 – 2008	3.145 Mbps
ARINC 629 (Serial)	1995	2 Mbps
MIL-STD-1760 (Fibre Channel)	1993 – Present	1.0625 Gbps
ARINC 825 (CAN)	2007	4 Mbps
ARINC 664 (AFDX)	2005 – 2009	100 Mbps
IEEE 802.3 (Ethernet)	1980 – Present	10 Mbps – 400 Gbps

Next gen data bus requirements

- Higher performance – bandwidth, latency, jitter
- Open, interoperable, evolvable standards
- Network convergence (SWaP)
- Compatibility with cybersecurity standards
- Lower "lifecycle" cost with broad industry support

Time-Sensitive Networking



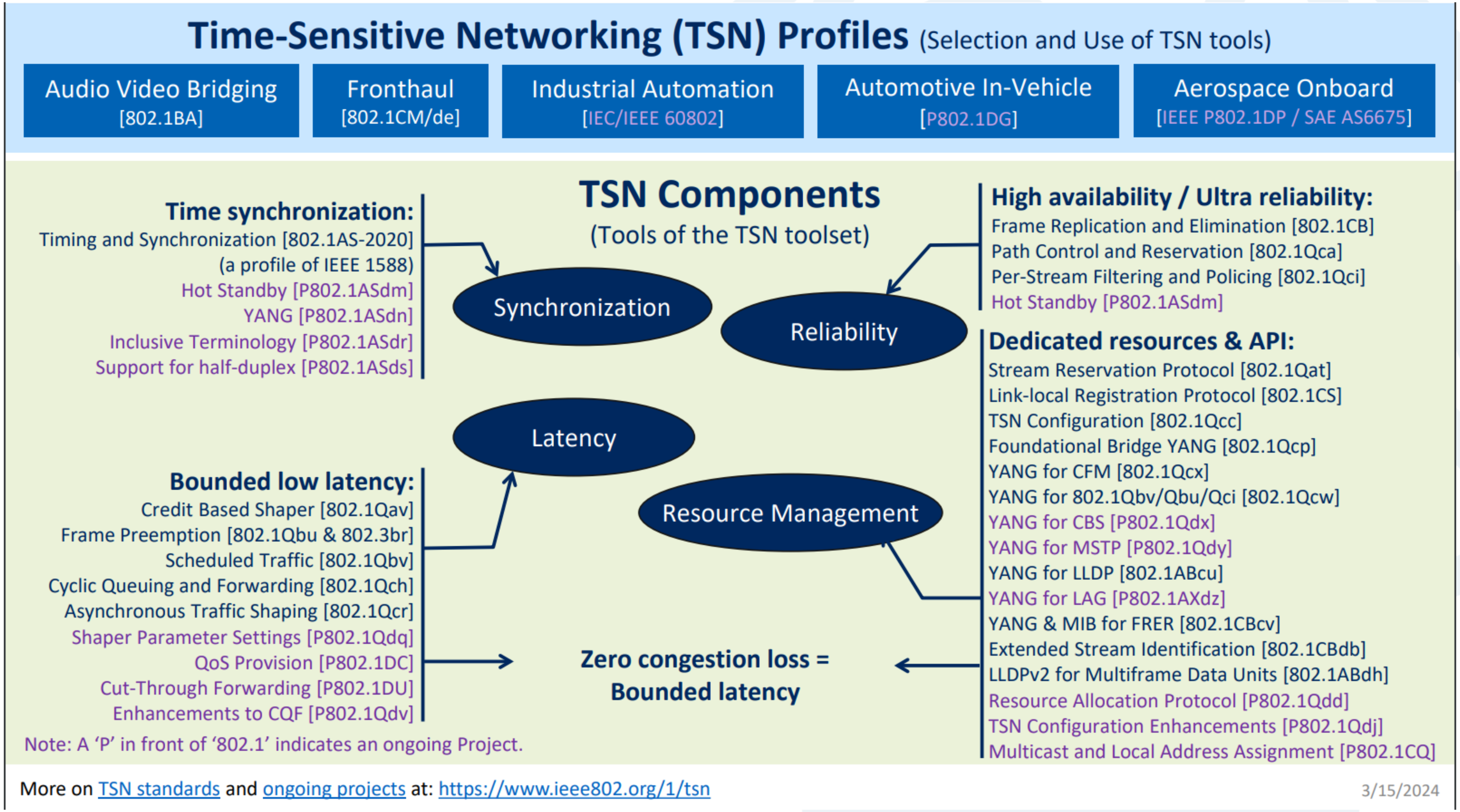
Technical Suitability

- Determinism and reliability
- High bandwidth, low bounded latency and jitter
- Network assurance on a converged network

Open Standards

- Interoperability - between devices, vendors, systems
- Scalability and Evolvability – of MAC and PHY
- Extensive vendor base for HW, SW, tools, and test equipment, supporting multiple industries
- Lower "life-cycle" cost

TSN Standards



Aerospace Profile Development

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Why Aerospace Profile

Use Case Perspective

- Static engineered networks
- Relatively small topologies
- Fully centralized configuration
- Specific requirements due to safety applications – high integrity, high availability, and fault tolerance
- Unique environment
- Long lifecycle (20yrs min, 50yrs expected)

Aerospace Industry Perspective

- Significant commonality across use cases
- Common TSN solution that meets aerospace network requirements
- Interoperability across devices and vendors
- Industry acceptance and certifiability as a common standard
- Increased vendor base
- Lower "lifecycle" cost

Well defined TSN profile provides an efficient solution for all aerospace use cases

IEEE and SAE JOINT WOKING GROUP

Joint Project

IEEE 802.1 TG
TSN Experts

+

SAE AS-1A
Aerospace Experts

+ Any interested person regardless of affiliation

Dual Logo Standard:

IEEE 802.DP / SAE AS6675

TSN Profile for Aerospace

Development

Project Approval
Dec 2020

Project Expiration
Dec 2026

Virtual Meetings

Weekly: Wednesdays
10:00 AM to 12:00 PM ET

Face-to-Face Meetings

3 IEEE Interim Sessions
3 IEEE Plenary Sessions
2 SAE AS-1 Meeting

Participation open to all without barriers
https://1.ieee802.org/tsn/802-1dp/

Aerospace Use Cases

Aerospace Use Cases

Commercial/Civil Aircraft

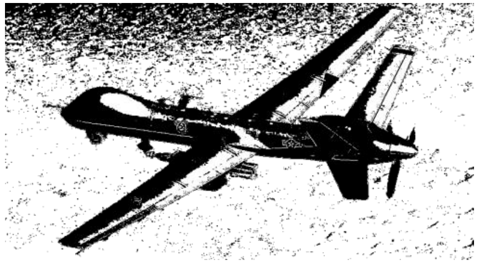
- Aircraft Control Domain Network (ACD)
  small and large passenger aircraft
- Cabin Network (ACD, AISD, PIESD)
  large passenger aircraft

Fixed Wing Military Aircraft

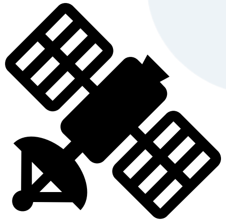
- Mission Network (small, combat, large)
- Flight Network (VMS)
- Fiber Channel over TSN (convergence)

Rotary Wing Military Aircraft

- Mission Network
- Flight Network



Unmanned Aircraft Network



Satellite

- Platform Network
- Payload Network

12 detailed use cases contributed by OEMs and Tier1/2/3 suppliers documenting both network and traffic characteristics

Use Case Summary – Topologies

Use cases inform the profile choices, but do not, in any way, limit the use for any aerospace application

Table 6-2—Summary of Aerospace Use Cases

Characteristic	Current Use		Known/ Desired Future Use	Use case driving the most restrictive bound
	Lower Bound	Upper Bound		
Number of Nodes	5	100	500	Large Passenger Aircraft (ACD)
Physical Topology	Bus (command/response protocol), Point-to-point/ multipoint, Ring (daisy chained), switched star or combination		Hybrid - Ring and Star	N/A
Number of Switch Hops	0	5	15-30	Large Passenger Aircraft (PIESD)
Max Number of Streams per Switch	50	2000	4096	Large Passenger Aircraft (ACD)
Network Redundancy	Two independent networks (A,B). End systems are dual homed to redundant LANs (ARINC664 part 7); Fault-tolerant Ring; None on point-to-point links. Subsystem or full system level redundancy (dual, triple, or quad)		same as current use cases	All fault-tolerant use cases
Redundancy Mode	Bus Failover (Hot Standby), Frame Failover (Hot Active); Hot Active with voting		same as current use	DAL* A/B systems
Data Rates	10 Kbps	1 Gbps	100 Gbps	MIL-STD-1553 and Satellites on the low bound. Military MS on the high end.
Media type	Copper: 1394,1553, RS-485/422, ARINC 429/629, Ethernet. Multimode Fiber: Fibre Channel, 100BASE-SX and 1000BASE-SX		Optical fiber for higher data rates	All aircraft

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Use Case Summary – Traffic Types

Use cases inform the profile choices, but do not, in any way, limit the use for any aerospace application

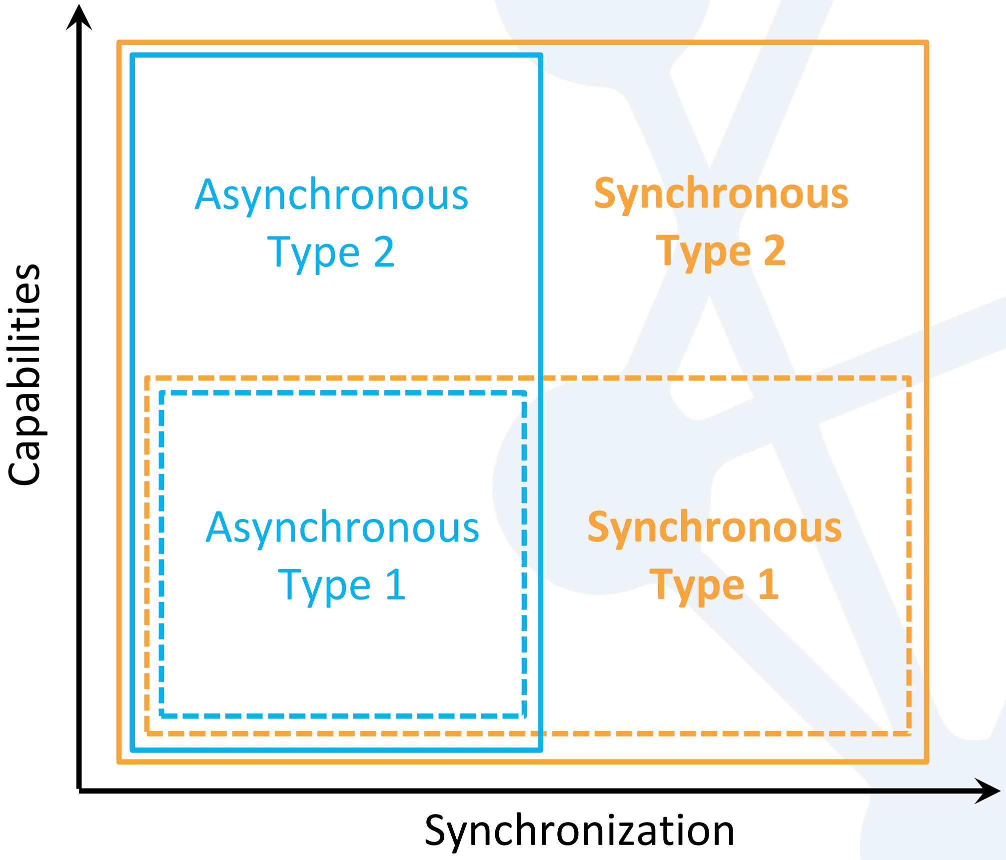
Table 6-4—Summary of Aerospace Traffic Types

Traffic Characteristic	Current Use (range)		Known/ Desired Future Use Bound	Use Case Driving the Most Restrictive (right) Bound
	Left Bound (loosest)	Right Bound (tightest)		
Synchronism	Asynchronous	Synchronous	no change	Ultra-low latency and/or jitter (right bound)
Application synchronized to network?	No	Yes	no change	Ultra-low latency and/or jitter
Periodicity or Cycle Time	Aperiodic	<1 ms	100 µs	Flight critical controls, sensors, and weapon systems
Latency Mode Guarantee Value	100 ms	1 ms	100 µs	high criticality asynchronous events
Tolerance to interference (delay variation/ jitter)	up to latency limit	< 1 µs	no change	fly-by-wire, synchronous sensors
Tolerance to Loss*	3 consecutive frames	zero	no change	Parametric data (left bound), Flight control or weapon release (right bound)
Payload size	8 bytes	2112 bytes	no change	Sensor data (left bound) Fibre Channel over TSN (right bound)
Data Criticality	no safety effect	DAL A	no change	Safety critical and flight control

Profile Specification

Conformant Profiles for End Stations and Bridges

Interoperable profiles enable a range of use cases

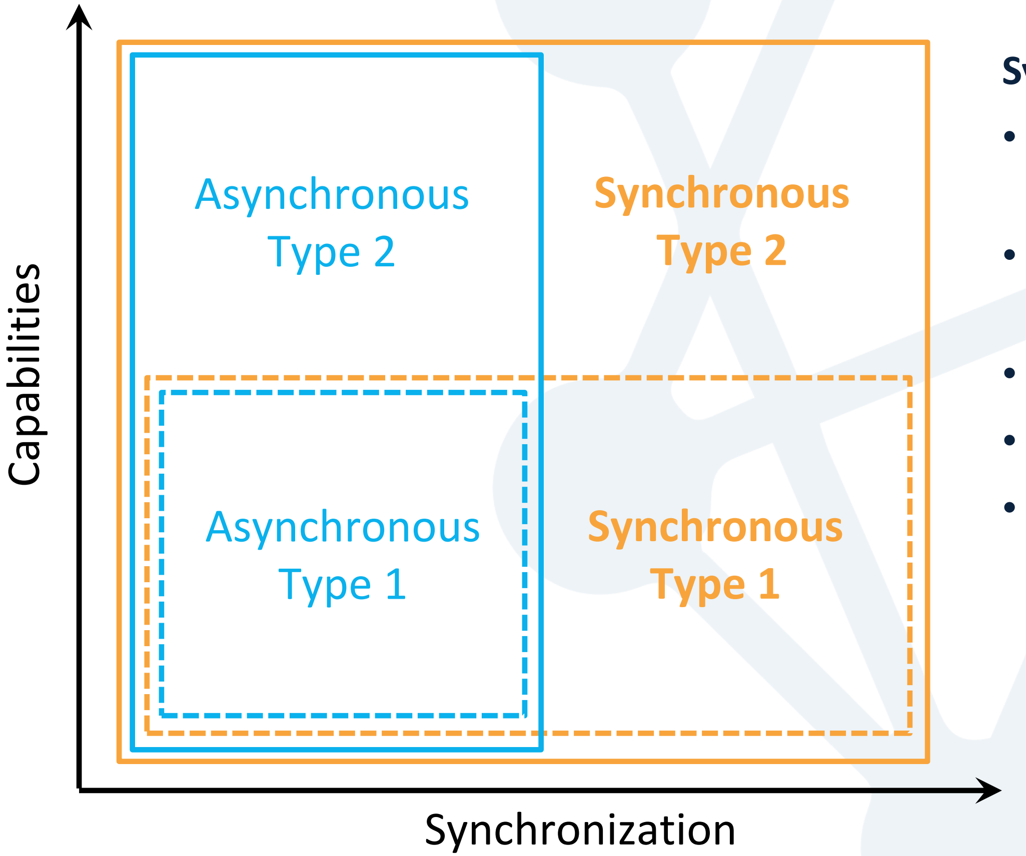


Conformant Profiles

Interoperable profiles enable a range of use cases

Asynchronous Profiles

- Asynchronous with slower cycle times (> 50 msec)
- Sensitive to latency but not delay variation (jitter)
- Single criticality traffic on a controlled network
- Simple network redundancy
- Common clock/time not required



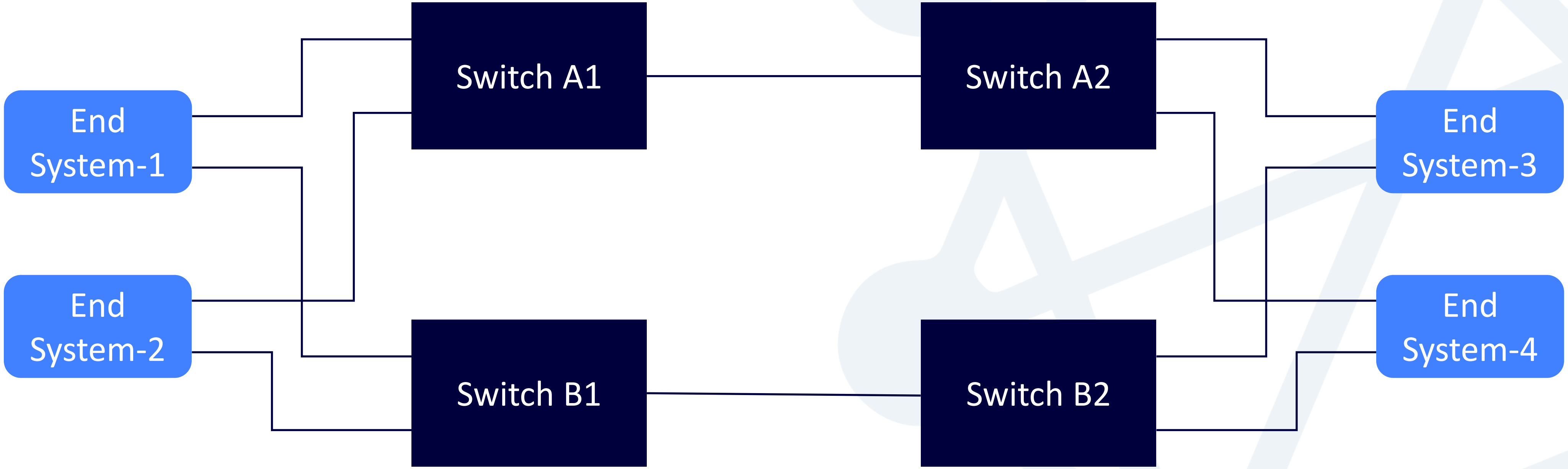
Synchronous Profiles

- Synchronous with cycle times in the order of 1 msec
- Sensitive to latency and delay variation (jitter)
- Convergence of mixed critical traffic
- Flexible redundancy
- Platform wide clock time distribution

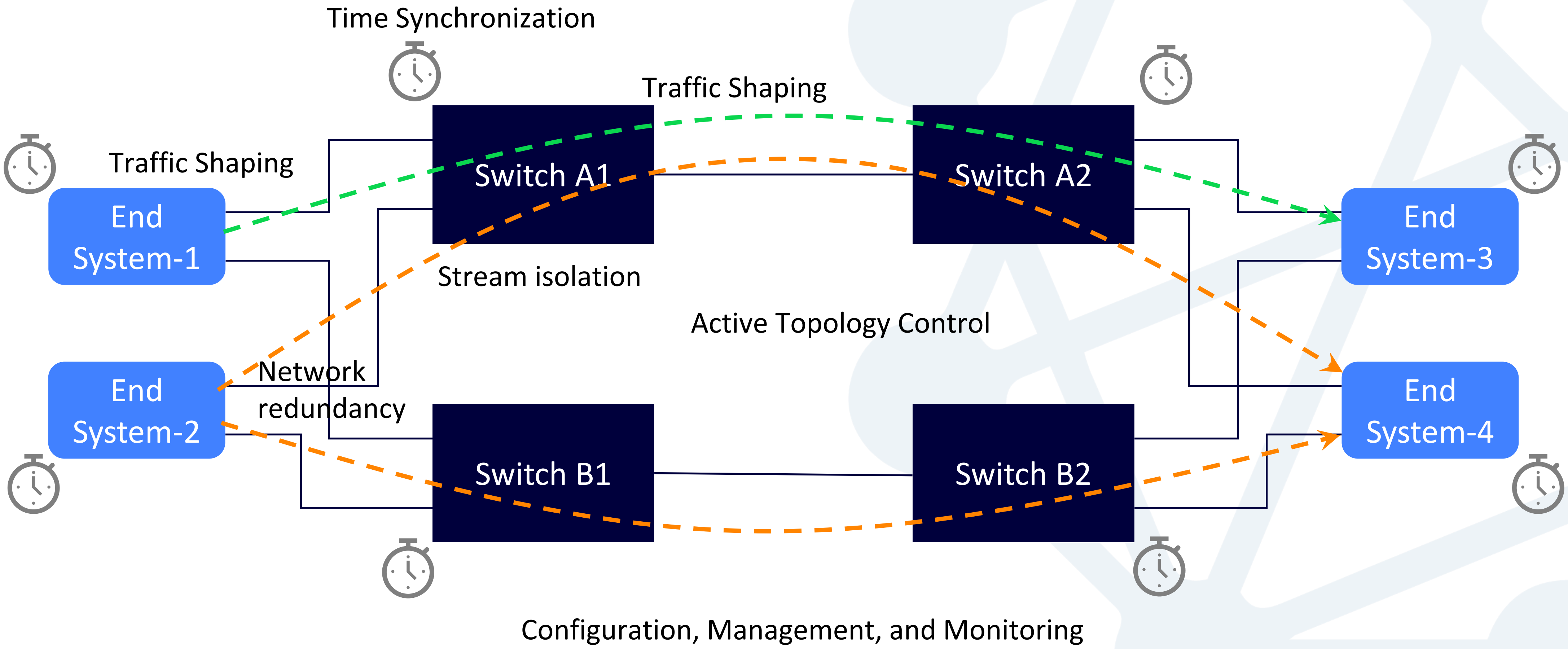
Required Functions for Aerospace Networks

Functions	Profile Specification	Relevant Standards
Time Synchronization	Generalized precision time protocol Fault tolerance with time integrity	802.1AS-2020* P802.1ASed
Traffic Shaping	Credit based shaper Time aware Shaper	802.1Q-2020, 8.6.8 Previously 802.1Qav and 802.Qbv
Redundancy	Frame replication and elimination	802.1CB-2017
Stream Isolation	Stream identification Per-Stream filtering and policing	802.1Q-2020, 8.8.5 Previously 802.1Qci
Configuration	Fully centralized with YANG modeled config data	802.1Q-2020, 46 802.1Qcw, 802.1CBcv
Active Topology Control	Per-stream static forwarding	802.1Q-2020
Management and Monitoring	Required error, fault, and performance metrics	802.1Q-2020

Aerospace Example



Aerospace Example – TSN Functions



Standardization Timeline

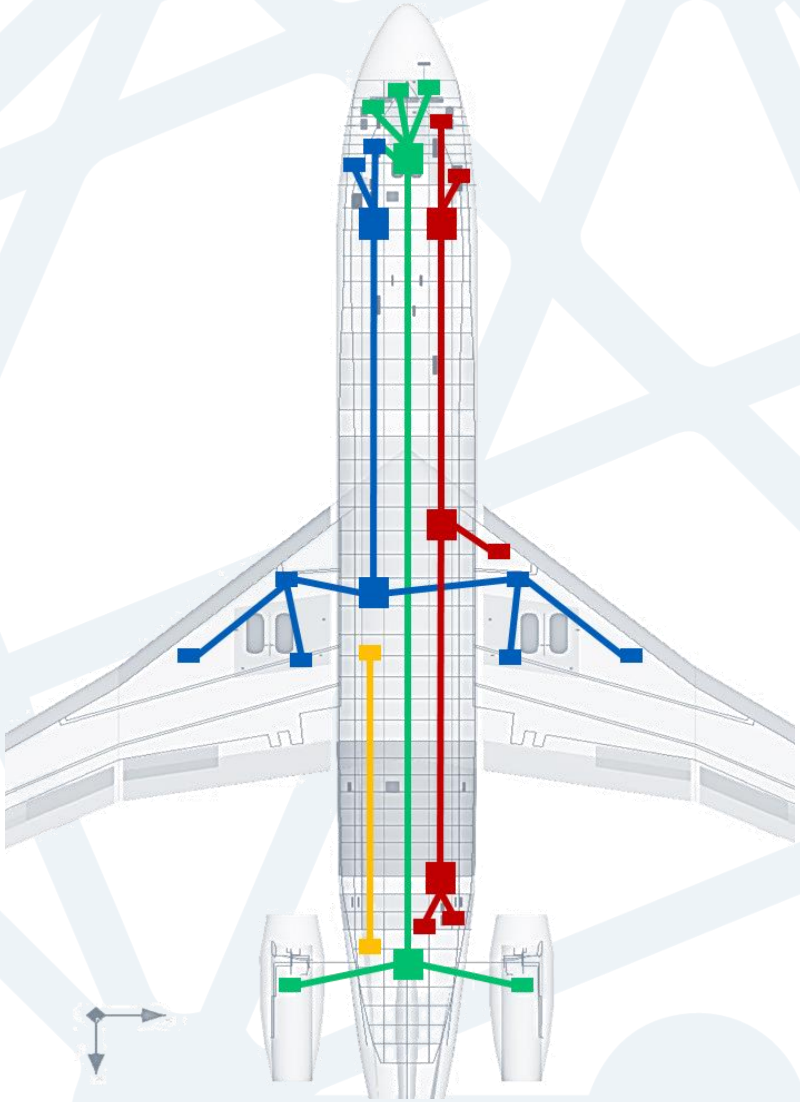
	2021	2022	2023		2024		2025 (estimated*)	
IEEE P802.1DP/ SAE AS6675	Use Cases and Requirements	Committee Development Draft 1.0	Balloting: IEEE TG SAE Sub-Comm	Update Draft Draft 2.0	Balloting: IEEE WG SAE Committee	Update Draft Draft 3.0	Balloting: IEEE SA SAE Counsel	IEEE/SAE Board Approvals Publishing
IEEE 802.1ASed (Time Integrity)		Initial Development	TG Ballot (as part of DP)	Split from DP	New project – Ased Draft 1.0	IEEE TG Ballots Update draft Draft 2.0	WG Ballots Draft 3.0 SA Ballots	Board Approval Publishing

** Future timeline is subject to standardization process*

Architectural Impact – Beyond Databus

Domain-Based Architecture

- Functional domains are realized with physically segregated networks
  flight controls, mission systems, displays/video, health monitoring
- Disparate data buses across domains on a given aircraft
- Gateways to convert data between networks/buses
- Federated system at a high level



Challenges

- Severe impact on size, weight, power, and cost (SWaP-C)
- Harnesses are very complex to manufacture and test
- Limits modularity due to design constraints

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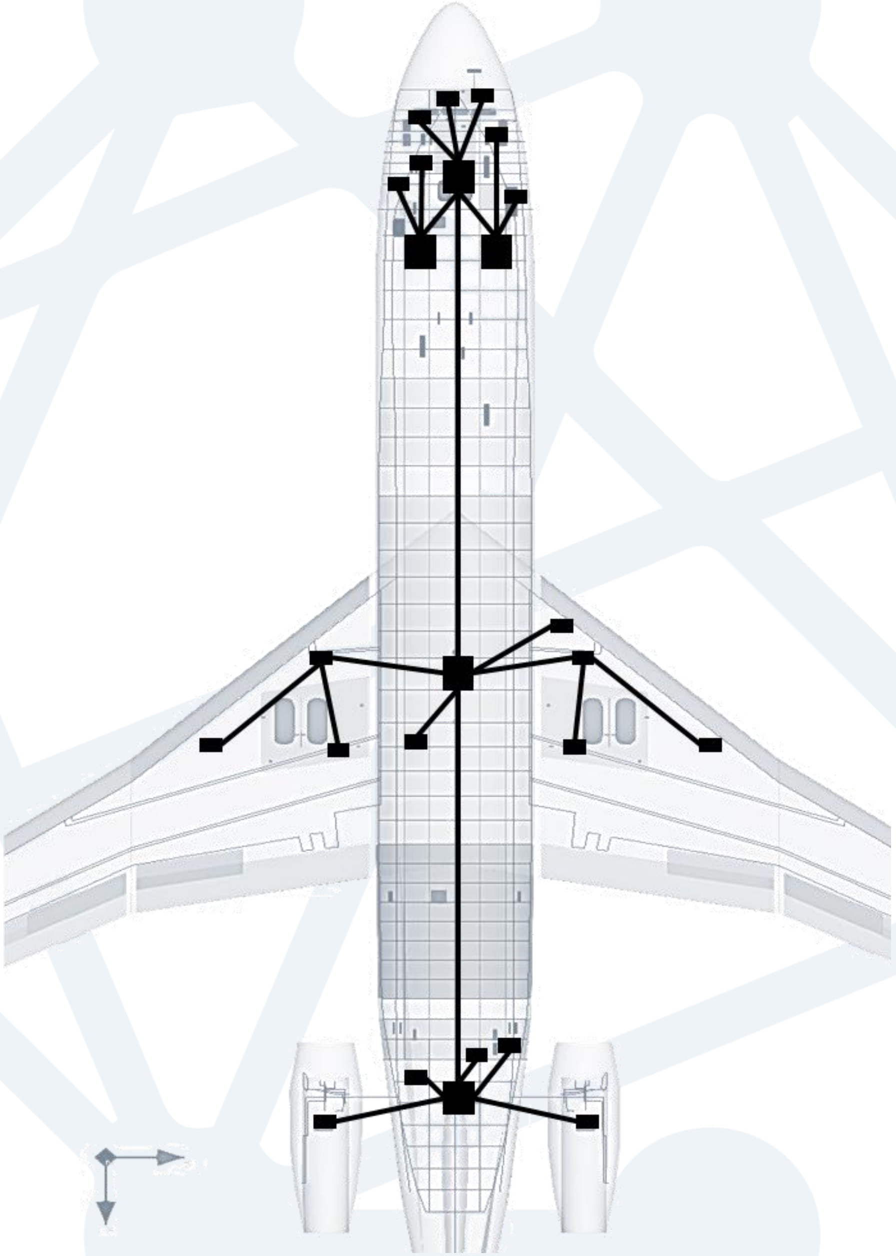
Zonal Architecture

- Converged physical network – "*digital backbone*"
- Logically isolated domains with performance guarantees
- Common open standards-based data bus/network
- Native support for data bus on all major components
- Zonal gateways to connect local I/O & legacy equipment

Benefits

- Reduces the size, complexity, and weight of the wiring
- Enables standardization and automation on networks
- Enables software and compute modularization



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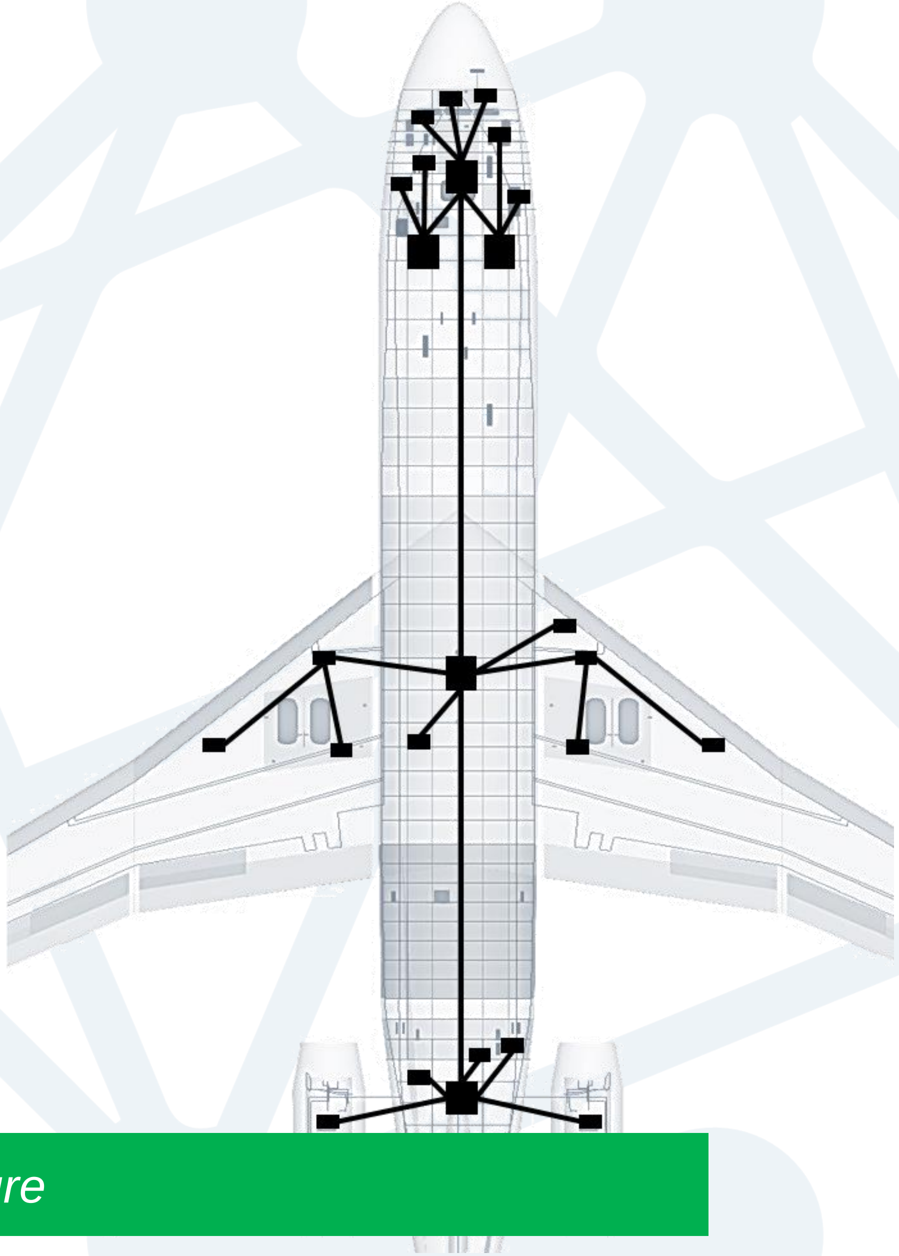
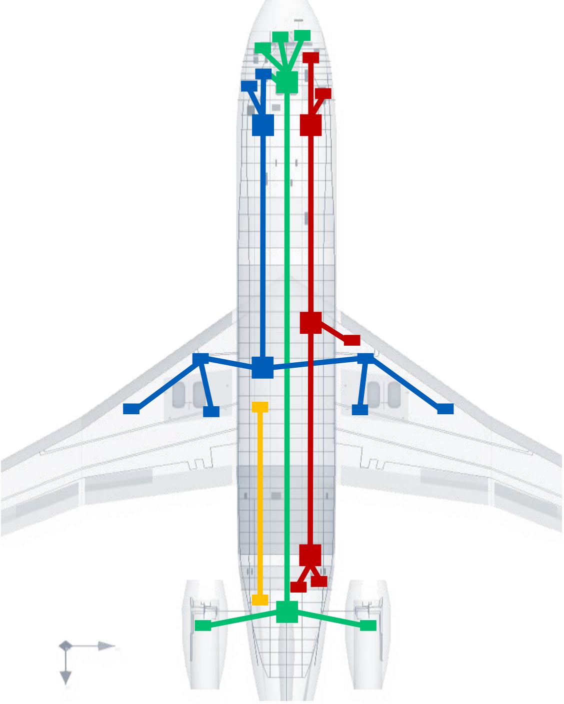


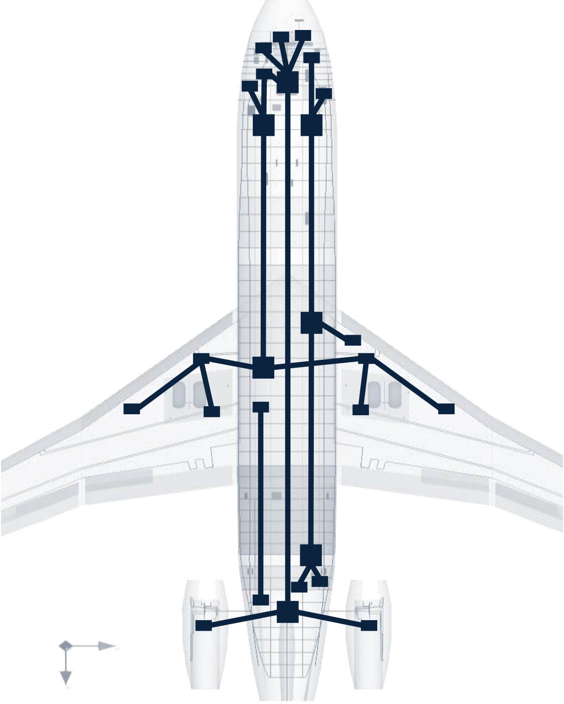
TSN Enables Zonal Architecture

Transition from Domain to Zonal Architecture

Domain-based Architecture

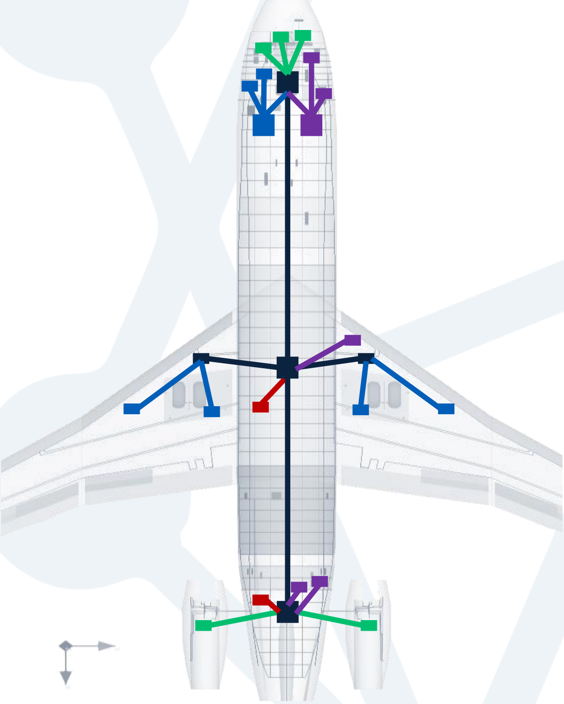


Segregated Network
Many Bus Types



Segregated Network
Fewer Bus Types

Zonal Architecture



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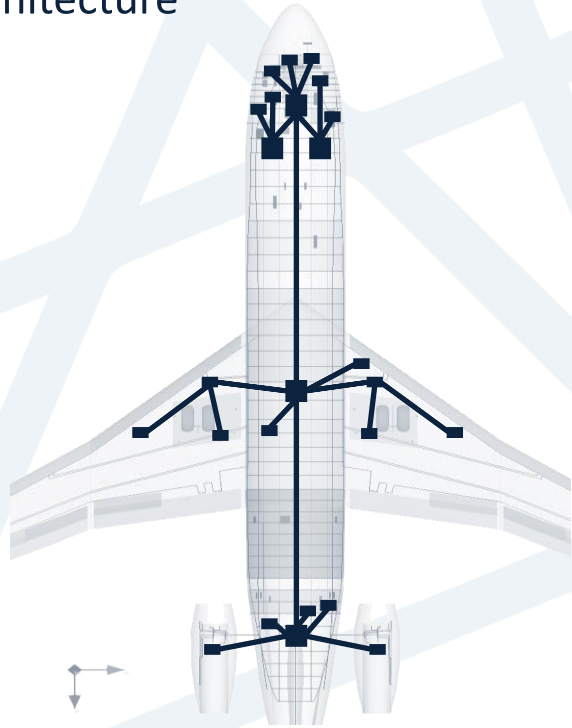

Converged Network
Fewer Bus Types

Summary

1. Aerospace industry has a need for an open standards-based, higher-performance databus.
2. Time-Sensitive Networking (TSN) elevates standard ethernet to meet aerospace requirements.
3. TSN profile for aerospace is being developed as a joint IEEE, SAE standard with participation from all stakeholders.
4. Profile selects features, options, and defaults to meet the unique requirements of aerospace use cases.
5. TSN enables zonal architectures with significant SWaP and modularity benefits.

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THANK YOU

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