TSN Applications in the Aircraft Cabin

COMMERCIAL AIRCRAFT

Cabin Electronics - Airbus Buxtehude
H. Lambers, W. Fischer, D. Kliem

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AIRBUS

What's so special about electronics for aircraft?

Manufacturing Lifecycle of different industries:

1-2 years

4-6 years

> 30 years

Example:

SA CIDS Director (1st Gen.)

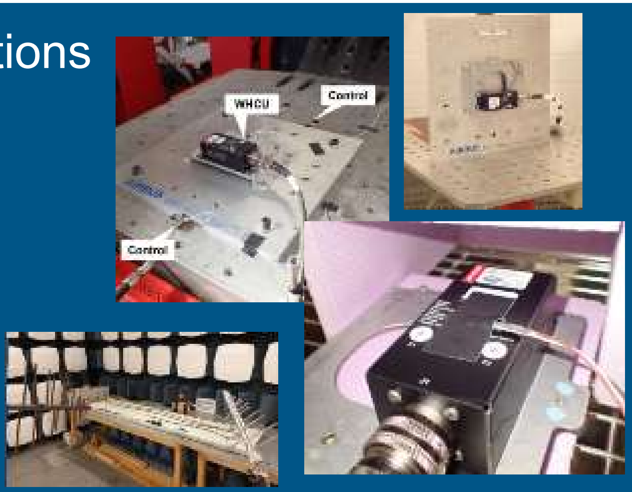
-Introduced 1988
- Still >> 2000 aircraft in service
- Cont. demand for spare parts
- Next obsolescence redesign already initiated

Characteristics of Cabin Electronic Equipment: (compared to non-A/C electronic products)

- Extensive Development and Qualification
- Small Quantities
- Long Manufacturing Life Cycles
- Extensive Operating and Service Life
- Continuous efforts to replace obsolete parts

Environmental Conditions

- Drip Water
- Vibration
- Temperature
- RF-Susceptibility
- RF-Emission
- Lightning
- Flammability
- Radiation

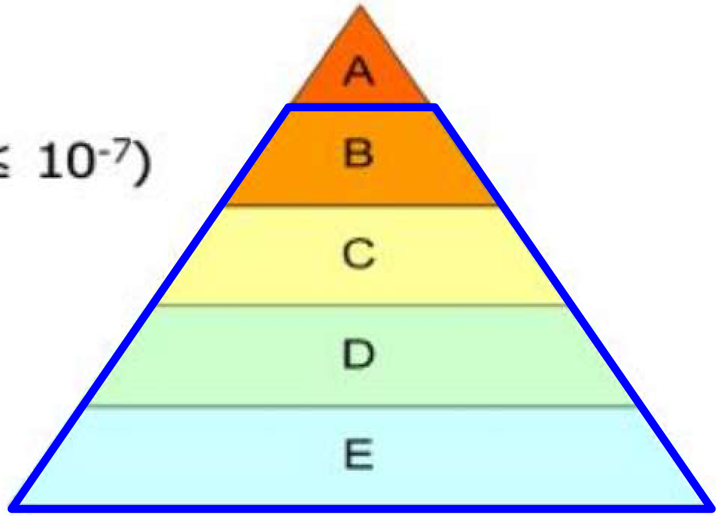


Aircraft Electronics: Low unit counts & long life cycles

Safety, Criticality & Certification - Design Assurance Level (DAL)

Safety Levels

- Level A: Catastrophic ($\leq 10^{-9}$)
- Level B: Hazardous/Severe ($\leq 10^{-7}$)
- Level C: Major ($\leq 10^{-5}$)
- Level D: Minor ($\leq 10^{-5}$)
- Level E: No Effect (N/A)



Cabin & Cargo Systems

Deterministic

- Bare Machine or Real-Time OS
- Embedded C
- Full requirement traceability
- Full test & code coverage
- Evidence for certification

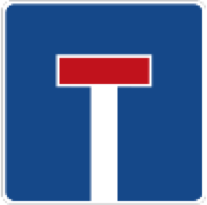
Non Deterministic

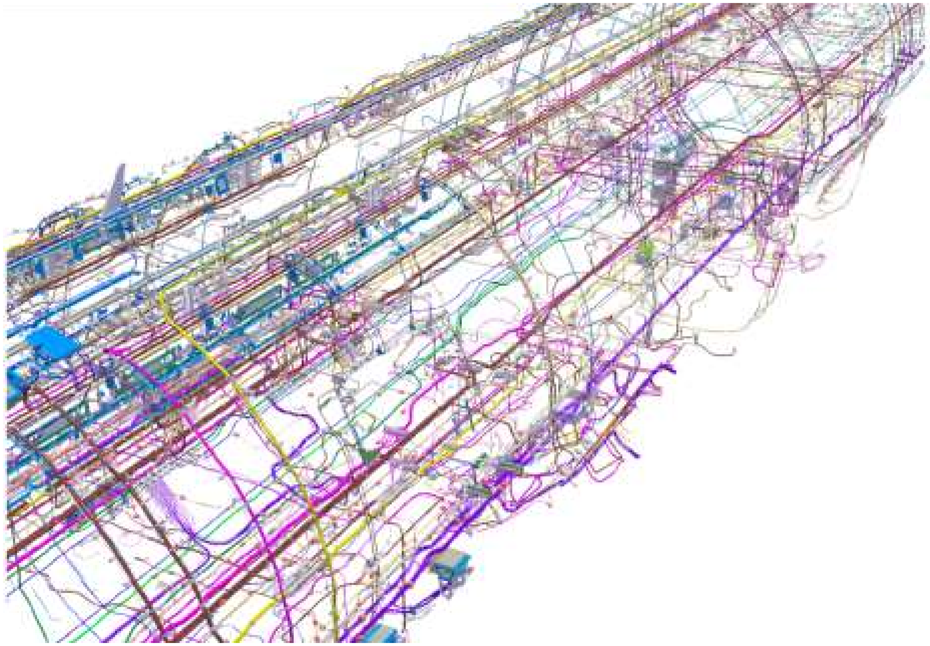
- COTS HW & SW Components
- All kinds of OSs & languages
- Less stringent
- Open Source

Shared systems must follow the highest DAL Level they serve!

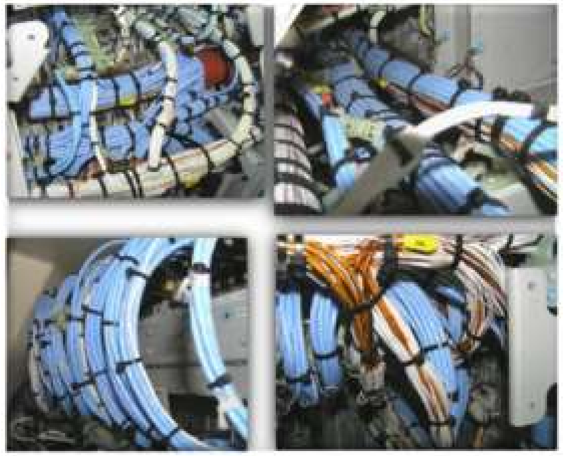
Todays Complexity in the Field

- Coexisting fit for purpose Systems => Limited growth capacities
- Various topologies, data transmission standards & interfacing technologies
  → ARIC429, AFDX, CAN, 'Discretes', Ethernet, RS485, UART, ….
- Many gateways → Development-, Production- & Maintenance Cost
- Any advantages?
  → Less cross effects between systems
- New applications
  ⇒ More data!
  ⇒ More bandwidth!
  ⇒ More cables & gateways?
  ⇒ More weight??





Source: Airbus



Source: Airbus

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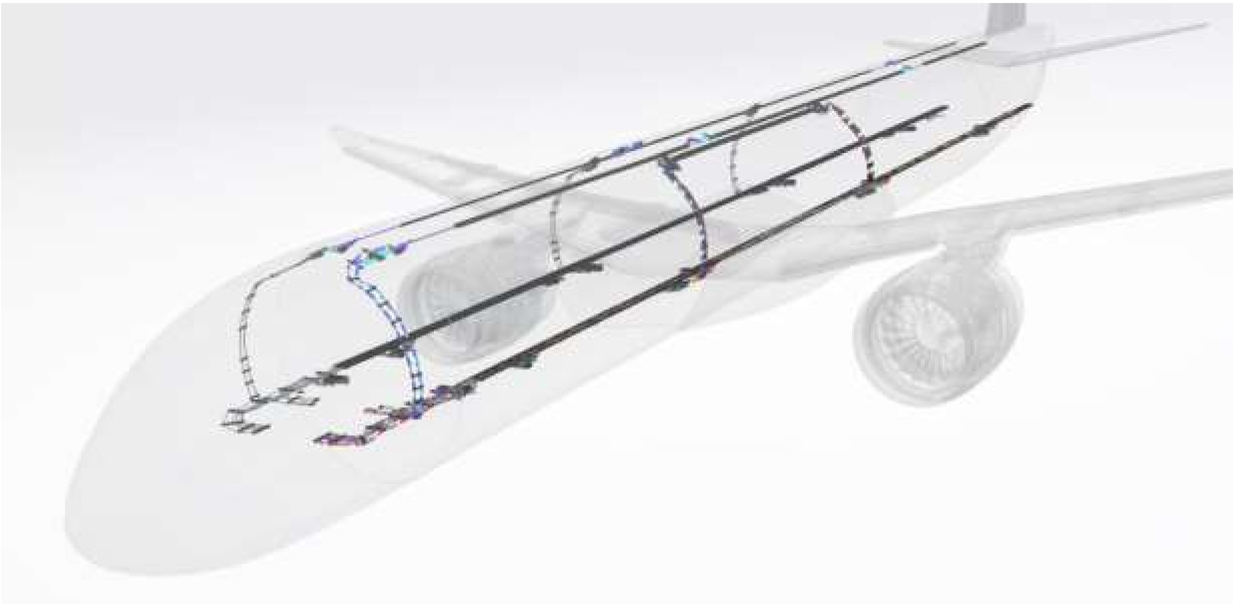
The Goal: Future Proof Data Networks + Improved SWaPC

Ethernet / IP network benefits:

- Scalability / Performance
- Physical layer technologies from backbone to "last meter*
- Stable Protocols - available over time
- Cost effective RCs → COTS based



Source: Airbus

Common network shared by many functions enabling
Size **W**eight **a**nd **P**ower and **C**ost + Performance improvements!

One of the remaining challenges: Determinism!

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TSN - The right Enabler?

	Networking Standards	Decision
Time Reference	802.1AS Timing and Synchronization	Mandatory
Scheduling	802.1Qbv Scheduled Traffic	Mandatory
	802.1Qbu & 802.3br Frame preemption	Optional
	802.1Qch: Cyclic queueing and forwarding	Dropped
	802.1Q Strict Priority	Mandatory
	802.1Qav Credit-based Shaper	Mandatory
	Other work conserving scheduler	Dropped
Configuration	802.1Qcc: Enhancements and improvements for stream reservation	Mandatory
Seamless Redundancy	802.1CB Frame replication and elimination	Mandatory
	High-availability Seamless Redundancy (HSR)	Optional
	Parallel Redundancy Protocol (PRP)	Dropped
	Spanning Tree Protocols (e.g. RSTP)	tbc
"Stream Control"	802.1Qci Ingress Policing	Mandatory
	Other Ingress Filtering & Policing methods (vednor specific)	Dropped

Very early thoughts still driven by TDMA idea

(802.1DP / SAE AS6675 was yet to come)

Time Synchronization (gPTP; 802.1AS-2011)	Time Aware Scheduler (TAS; 802.1Qbv)	Per Stream Filtering & Policing (PSFP; 802.1Qci)	Credit Based Scheduler (CBS; 802.1Qav)	Frame Replication and Elimination (FRER; 802.1CB)
Maintain a precise time reference in the network	Guarantee a hard data delivery deadline	The police' managing e.g. babbling idiots, etc.	Ensure a "smooth" & timly data delivery	Seamless Redundancy - without interruption
1588v2 works only among switches, but not with IXIA			HW Bug (Proposed Option Frame Based Shaper)	Interference with PSFP (FW issue)
	Basic functionality only (A0 HW limitation)	Requires HW revision B0 (Q3/22)	Requires HW revision B0 (Q3/22)	Requires HW revision B0 (Q3/22)
		Basic functionality passed More Testing in Progress	Scheduled in July rel.	More tests in big topology

First hands on impressions

Markets and standards implementation still evolving

…. don't try everything at once!

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Airbus Amber

Cabin Management Functions

- Audio & Music
- Cabin Lights
- IoT Device Connectivity
- IFE Integration
- Cabin Air Conditioning
- Satellite/Ground Connectivity
- Video Surveillance
- Doors & Slides
- Wireless Connectivity
- Doors & Slides
- **Smoke Detection**
  DAL B System
- Evacuation Signaling
- Passenger Signs
- Crew Interphone
- Passenger Address

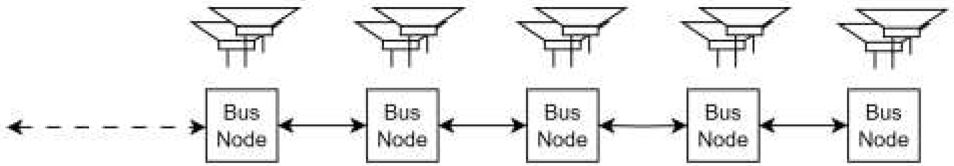
and much more (50+ applications)

Safety & Security, Efficient Crew Operations and Passenger Comfort.

Airbus Amber

New Complexity - Example 1: Power Consumption

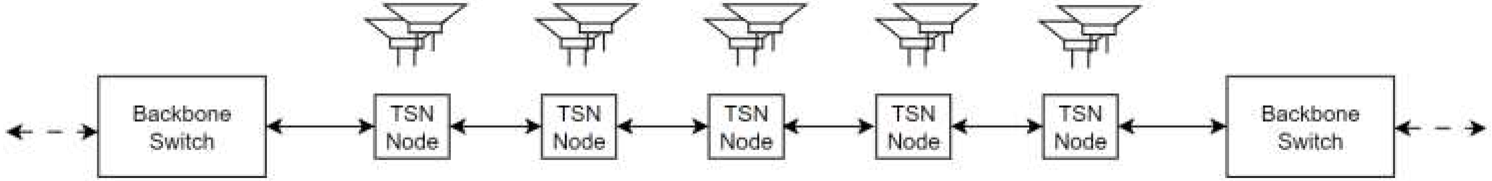
Todays proprietary bus system in service:



Source: Airbus

A350 DEU-A - Bus Node as in Service today

Future system using Ethernet & TSN (generic topology):



If you give an engineer a faster data bus …

… he will ask for more power

More performance drives more, new applications, but also higher power needs!

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New Complexity - Example 1: Power Consumption

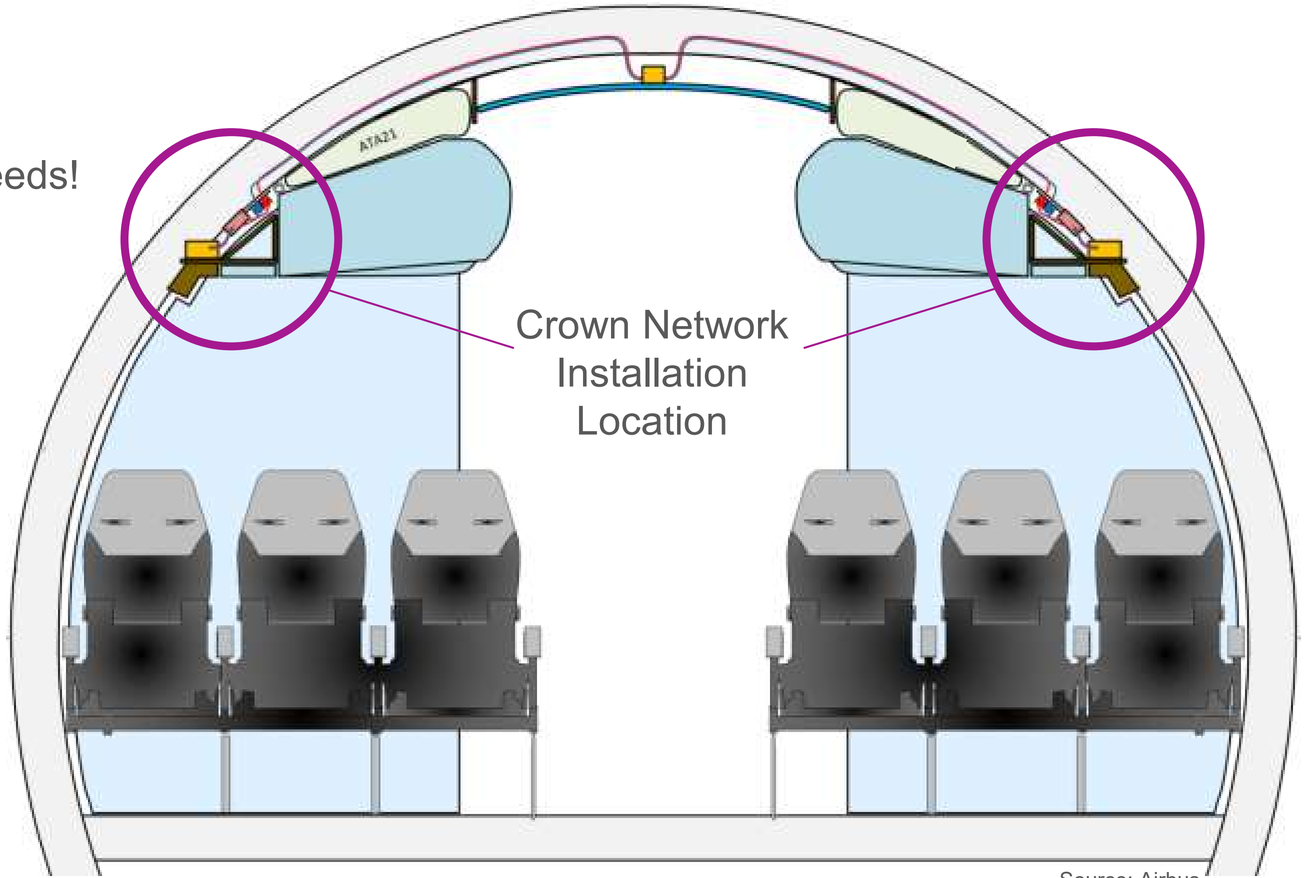
Power Supply:

- The Electric power distribution system must cover all needs!
  ⇒ Electric power distribution is a “High” DAL function
  ⇒ Higher currents → Thicker cables → Weight
  ⇒ Potential adverse SWaPC impacts

Crown Equipment Location Overview

- Limited installation space
- No forced cooling available
- No active cooling → Less maintenance effort

⇒ Limited heat dissipation capacity!



Single Aisle cabin Cross Section

Source: Airbus

Power efficiency is key!

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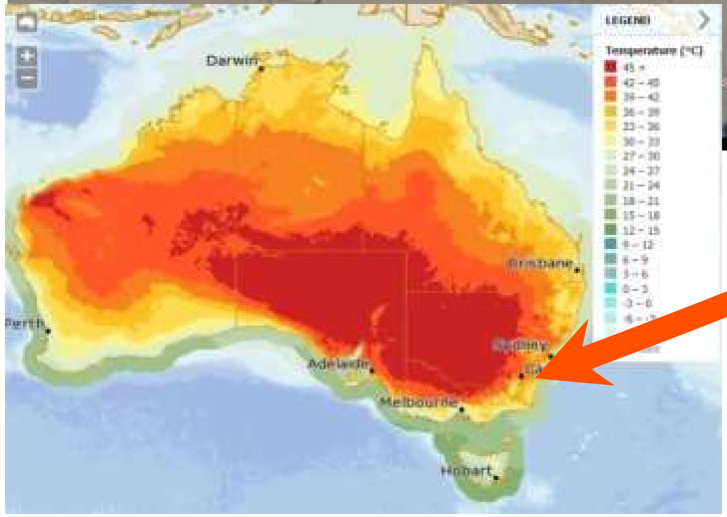
New Complexity - Example 1: Power Consumption

Now imagine …

Source: Airliners.net

… your A321
is parked here:



Source: www.bom.gov.au

Canberra in January:
→ Mean daily maximum 28.8 °C

Each watt counts!

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New Complexity - Example 2: Passenger Address (PA) Function

Some Key Requirements … :

- Max round trip delay microphone to all speakers: 35ms (Lip Sync.)
- Max speaker to speaker delay: 1ms
- Design Assurance Level: C
- System availability in Emergency Power Mode: 500 ms (based on EASA CS-25)

Source: Airbus

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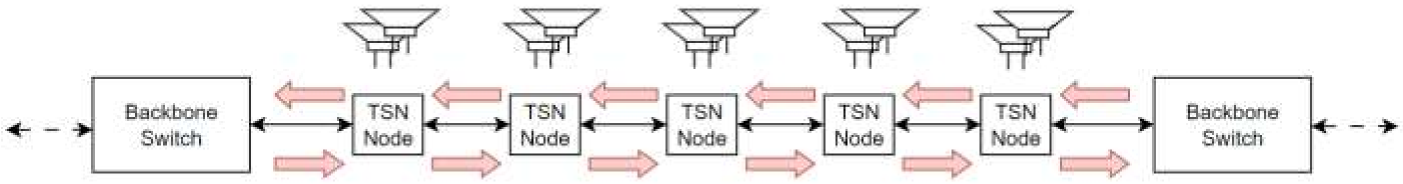
New Complexity - Example 2: Passenger Address (PA) Function

Some Key Requirements … :

- Max round trip delay microphone to all speakers: 35ms (Lip Sync.)
- Max speaker to speaker delay: 1ms
- Design Assurance Level: C
- System availability in Emergency Power Mode: 500 ms ?

… and how to implement them:

Generic Topology:



- TSN features used for implementation:
  - Meet latency requirements and ensure proper audio rendering: 802.1Qav (FQTSS) & 802.1AS (gPTP)
  - Ensure Reliability & Robustness to meet DAL-C requirements: 802.1CB (FRER) & 802.1Qci (PSFP)

Requirements met - no need yet for TAS (Qbv)

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- Design Assurance Level: C
- System availability in Emergency Power Mode: 500 ms **?**

… What actually means: Emergency Power Mode?

- Use Case: Total Loss of Main Electrical System (TLMES)
  ⇒ Requires rigorous housekeeping to conserve electric power
  ⇒ Parts of the system will be re-powered only if required
  ⇒ The Handset PTT button triggers re-powering the full PA Function

Air Transat Flight 236 after the emergency landing

Source: FAA (Public Domain)

How to realize 500ms startup time?

New Complexity - Example 2: Passenger Address (PA) Function

Some Key Requirements … :

- …
- System availability in Emergency Power Mode: 500 ms

… Rapid power up enabler and limitations:

- Hardware & software component selection for rapid power up
  ⇒ FPGA based hard wired switch IPs
  ⇒ Small, fit for purpose, fast booting SW footprint

- Layer 1 time to link + gPTP Re-Synchronization across multiple hops are setting a limit
  ⇒ Rigorous control of power consumption requires more complex power management potentially adding weight too
  ⇒ Emergency Power Up requires a “work around” TSN - PA will be the only application running this ‘corner use case’

Source: Airbus

Up to 50 speakers are installed in an A321 aircraft

Specific aircraft requirements can add substantial complexity

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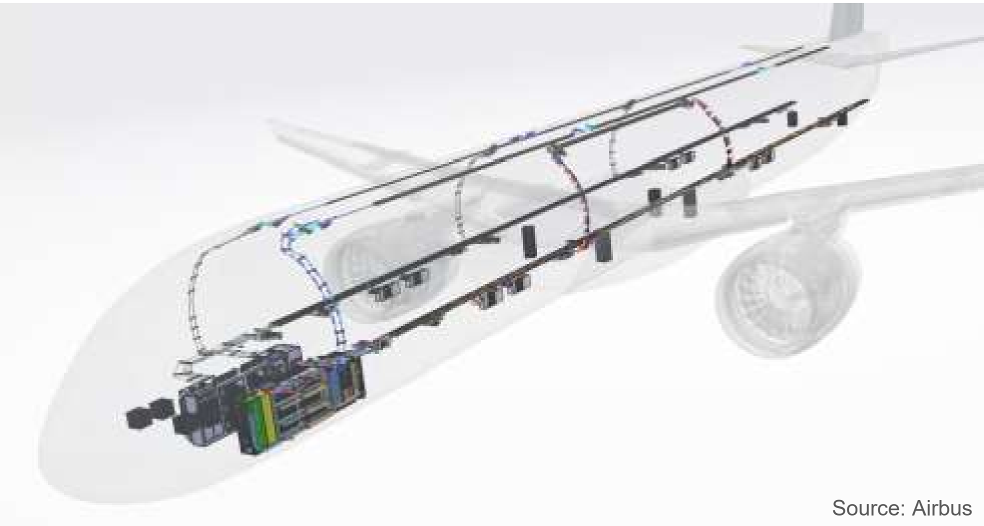
New Complexity - Example 3: Switch & SW Complexity



Source: Airbus

Switch location & sizing:

- Ebay & Backbone: → High port count @ high throughput; Scalability
- Cabin network: → Typically two backbone ports + Endpoint ports of different port types and sizes

Use cases require HW sourcing from multiple network market segments

New Complexity - Example 3: Switch & SW Complexity

Certification view on software for airborne systems:

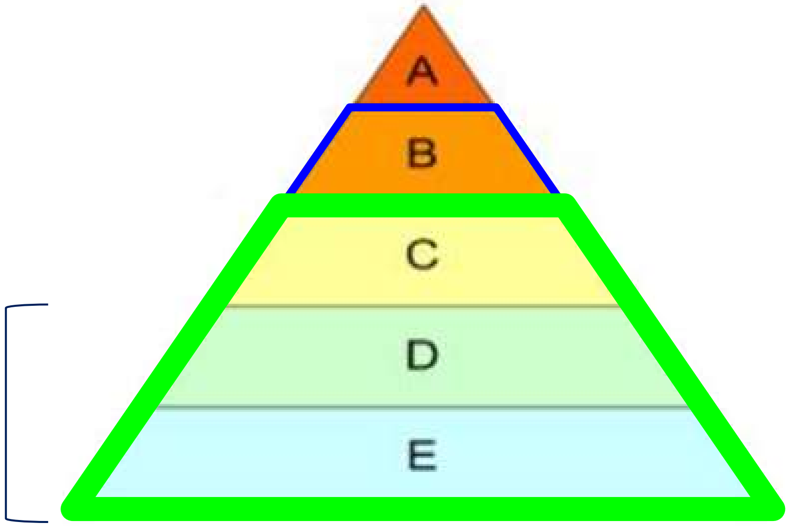
- DO-178: Software Considerations in Airborne Systems and Equipment Certification
- DO-331: Model-Based Development and Verification Supplement
- DO-332: Object-Oriented Technology and Related Techniques Supplement
- There are more …

DAL-A is out of cabin scope

One Application: Smoke Detection

Requires dedicated OS to meet DAL-C objectives

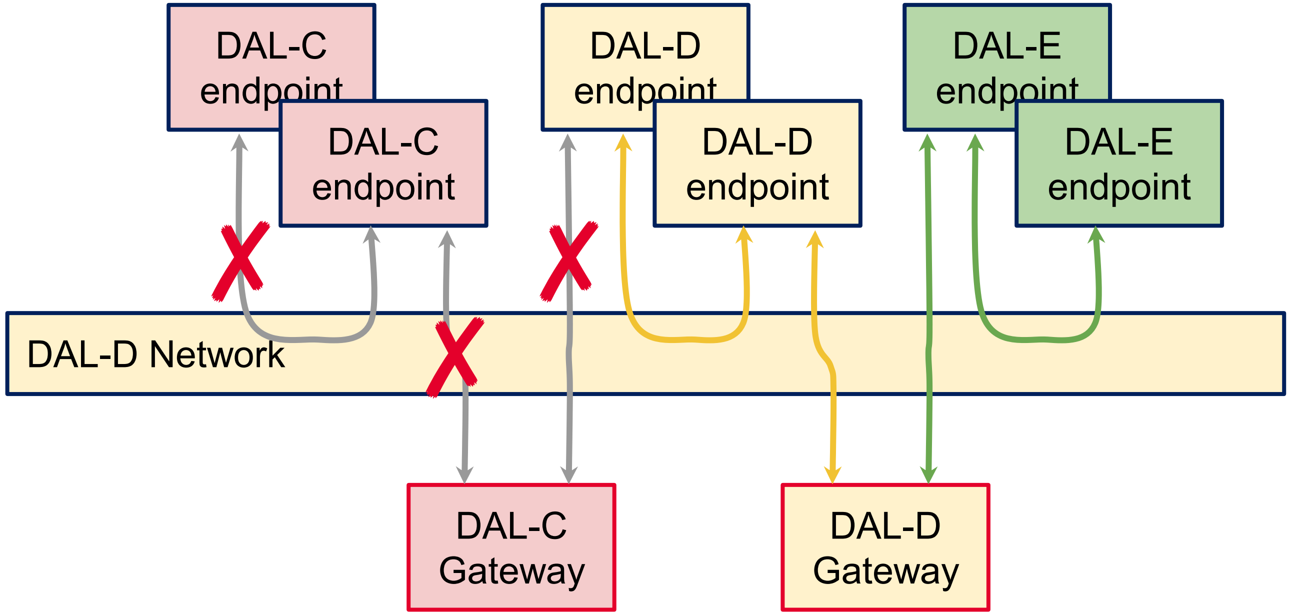
Standard COTS OS (e.g. Linux) can be reused



Goal: Identify COTS HW **suitable** for DAL-C certification

New Complexity - Example 3: Switch & SW Complexity

Data transmission across a shared network:



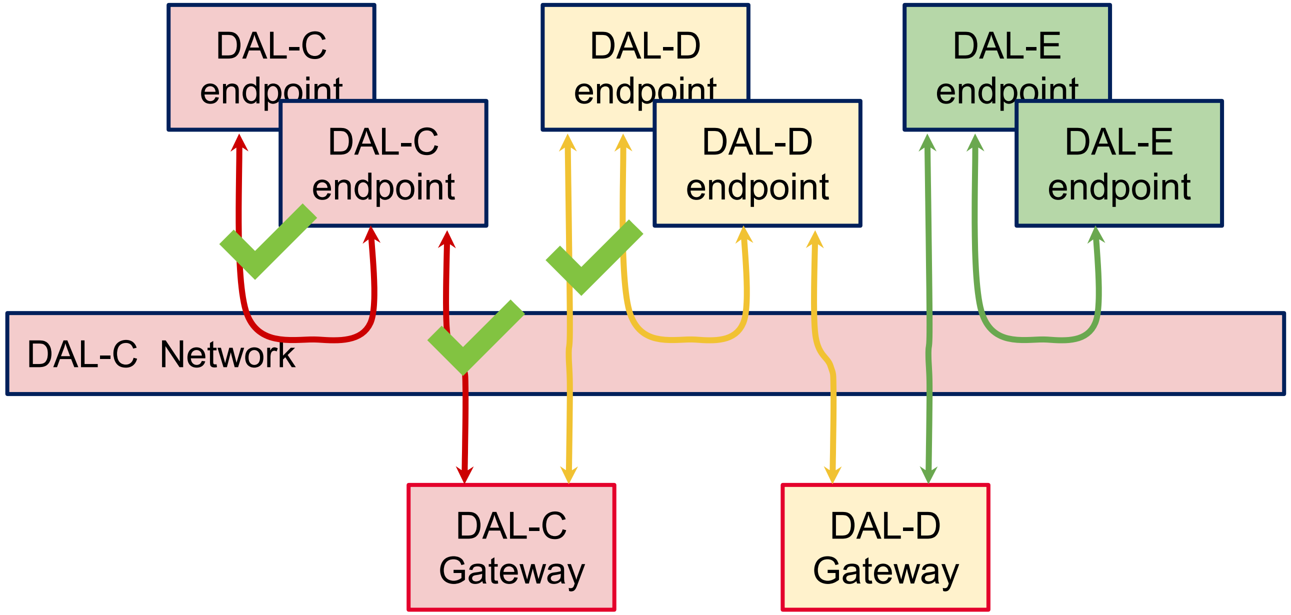
New Complexity - Example 3: Switch & SW Complexity

Data transmission across a shared network:

- Meeting DAL-C objectives means e.g.:
  - Requirements based code coverage
  - Independent checking & testing

⇒ Typical COTS switch SOCs are feature rich and based OS's where DAL-C certification is way too complex!

⇒ We need a certifiable OS & application SW!
⇒ And we need to keep it simple / fit for purpose!



High DAL certifiable SW is an asset!

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In a nutshell

Performance without sacrificing SWaPC

Stable protocols & scalable interfaces with less obsolescence hassles expected

Complex technology requires standardization - 802.1DP / SAE AS6675 is important

COTS components require an aerospace (SW) finishing - Aerospace specific challenges still exist

The network will be seen as a independent system
providing services to other systems

Questions?

Thank you