IRT SAINT EXUPÉRY

TSN for critical embedded systems

TSN for critical embedded systems

ETR 2021 Poitiers/Futuroscope Sept. 2021

EDEN Team

Philippe Cuenot - IRT Saint Exupéry (Segunded from Continental Automotive)

Agenda

- ❑ Context of the study
- ❑ Pre-analysis of TSN Services
- ❑ Case studies
- ❑ Tool Framework
- ❑ Perspectives

CONTEXT OF THE STUDY

EDEN Team

IRT Saint Exupéry Identity

The IRT is a collaborative and integrated technological research center bridging the public research to the industrial one.

Technologies that are developed answer to industrial needs, benefiting of the academic researches.

IRT Saint Exupéry is a private research foundation supported by the French State funding projects in proportion to industrial contribution and defining the regulatory framework of the foundation.

MEMBRES FONDATEURS

cnrs	cnes CENTRE NATIONAL D'ÉTUDES SPATIALES
Université Fédérale Toulouse Midi-Pyrénées	ACTIA
AIRBUS	LIEBHERR
THALES	SAFRAN

FRENCH INSTITUTES OF TECHNOLOGY

IRT SaintExupéry: Toulouse Site • B612 Building.

« an ecosystem of collective intelligence »

The B612 building is the totem in terms of developing and accelerating innovation. It is also the amplifier of national and international influence of the Toulouse metropolis.

B612 Acceleration

In order to support companies and innovative projects in the aeronautics, space and embedded systems sectors, the B612 proposes an acceleration offer at the heart of the ecosystem, supported by Toulouse Métropole and Aerospace Valley

RESIDENT STRUCTURES

24 000 m²

of total surface

10 900 m²

for IRT Saint Exupéry

8

companies

298

people @IRT Saint Exupéry

IRT Saint Exupéry: mission

Promote

Promote French technological research for the benefit of the industry established on the national territory.

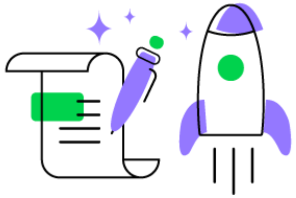
Develop

Develop the local ecosystem for aeronautical & spatial sector and critical systems.

Create

Create a link between the public and private research in order to :

- Bridge the two worlds and ease the transfer and implementation of the research within the industry.
- Resourcing thanks to the fundamental research for the benefit of the technological research.



Realize

Realize research projects from the industrial needs, integrated, with an upstream contribution from the academic community, supported and funded par the French state and the industrial members.

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IRT Saint Exupéry: Markets and Organisation

Target Markets

- Aeronautics
- Space
- Defence

« Synergy » Markets

- Railway
- Land Mobility
- Energy
- Medecine
- Environment / meteo
- Maritime

12 competences @IRT Saint Exupéry

- High voltage energy >
- High Reliability Energy >
- High density energy >
- Metallic materials and processes >
- Surfaces / assemblies >
- Composite materials >
- Advanced Learning >
- AI for critical systems >
- Autonomous Connectivity & Detection >
- Systems Engineering >
- Multi Discipline Optimization >
- Critical Embedded Systems >

4 Technological Axes @the service of industrialists

- Greener Technologies
- Advanced Manufacturing Technologies
- Smart Technologies
- Methods and tools for the development of complex systems

Design efficient & secure hardware and software architectures

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EDEN Project

Evaluation of a Deterministic Ethernet Network

Objectives: Get full confidence and enable deployment of Ethernet Time Sensitive Network (TSN) as embedded network for multi domains architectures (aeronautic, spatial and automotive)

36 months

1/06/2020

10 Members

Industrials	Acamedics	Collaborations
Airbus Operation	IRIT*	Silicon Suppliers
Airbus D&S	ISAE	Tool Suppliers
Continental	ONERA	
CNES		
Safran Electronics and Defence		
Thales Alenia Space		
Thales Avionics		

*PhD Thesis

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EDEN Project

Challenges for embedded critical systems

New requirement for increased network performance

Reduce cost by using COTS for embedded network

Unification of network support using Ethernet

Aeronautical sector :

Define an alternative to AFDX with a low footprint and low cost solution.

More efficient with the same quality of service.

Space sector :

Unify network for platform communications and payloads with increased performances at low footprint.

COTS as IP in space FPGAs (Switch and Endpoint) at low cost.

Challenges for the automotive sector :

New communication needs beyond low costs and footprint required by autonomous vehicle.

Enable off-the-shelf systems in standard Ethernet on the same critical and certifiable network.

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PRE-SELECTED TSN SERVICES

EDEN Team

IEEE Standard Analyzed

Quality of Services
IEEE802.1Q-2005: Bridges and VLAN Network
IEEE802.1AB-2016: Station and Media Access Control Discovery
IEEE802.1AX-2014/2020: Link Aggregation (LLDP)
P802.1Qcj: Automatic Attachment to provider Backbone Bridge

Synchronization
IEEE802.1AS-2011/220: Timing and Synchronization

Reliability
IEEE802.1ag-2007: Connectivity Fault Management
IEEE802.1Qca-2015: Path Control and Reservation Mechanism
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Standard not selected as not suitable for critical system

No dynamic discovery and attachement required

Quality of Services

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Congestion monitoring with data center supervision

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Standard not mature

FRER extension under development

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Qos and Synchronization

Reliability

TSN

Latency

Resource

Under development
no additional services

Resource reservation
under development

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Standard left out (not priority)

Implementation specific – redundancy with FRER

Benefit on safety tbc - discarded from now

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Standard outdated

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Qos and Synchronization

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AVB updated by CBS

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Standard considered for toolset development

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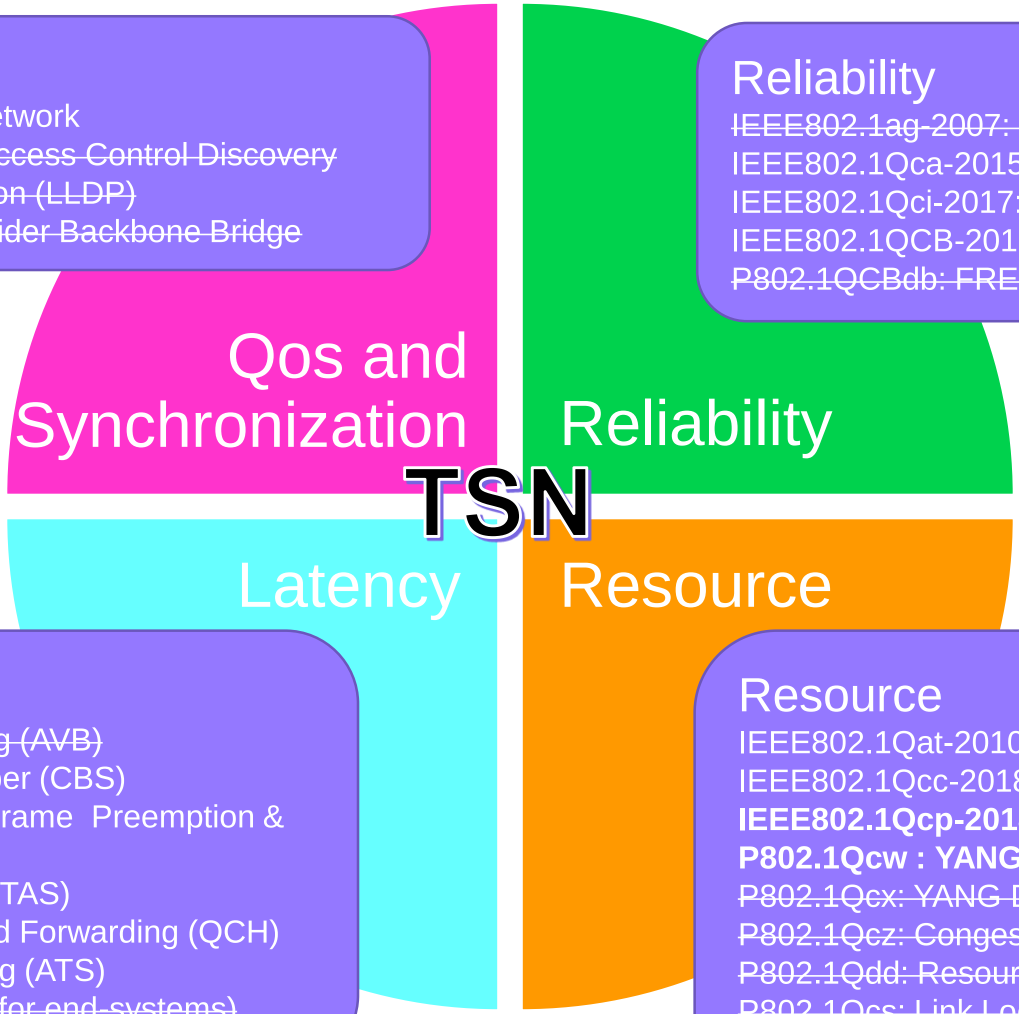

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Standard considered for network configuration

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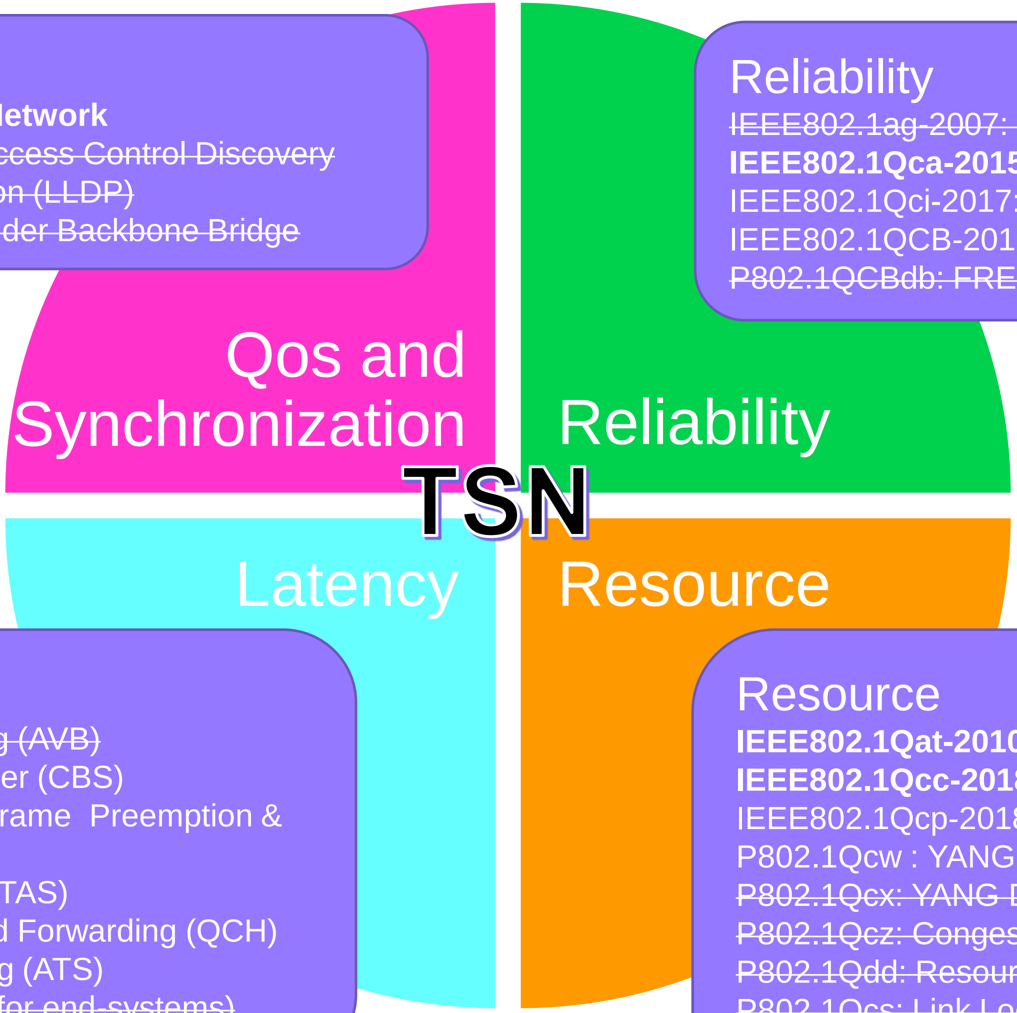

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Standard for TSN configuration (scope of study)

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TSN Prospective guideline

Standard	Use case
802.1AS	Clock synchronisation mandatory
802.1Qav (CBS)	Transport of multimedia flows but with shared support for control command
802.1Qbu (Preemption)	For use case of large size ratio between large and small frames when small frames get high priority and low latencies and jitter.
802.1Qbc (TAS)	For high priority and low latency and jitter control frames
802.1Qch (CQF)	For small to medium sized systems but is to be demonstrated
802.1Qcr (ATS)	Same use as CBS on small systems and could provide an advantage of not causing a burst. (very recent and requires theoretical studies)
802.1Qci (PSPF)	Necessary to protect against errors such as routing, babbling-idiot, etc
802.1CB (FRER)	To protect against loss of links and communication nodes
802.1Qat & 802.1Qcc	Seems necessary to configure the resource demands in bridges either statically Qcc or dynamically Qat (SRP) or a hybrid of both

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Case studies

Automotive
Space
Avionics

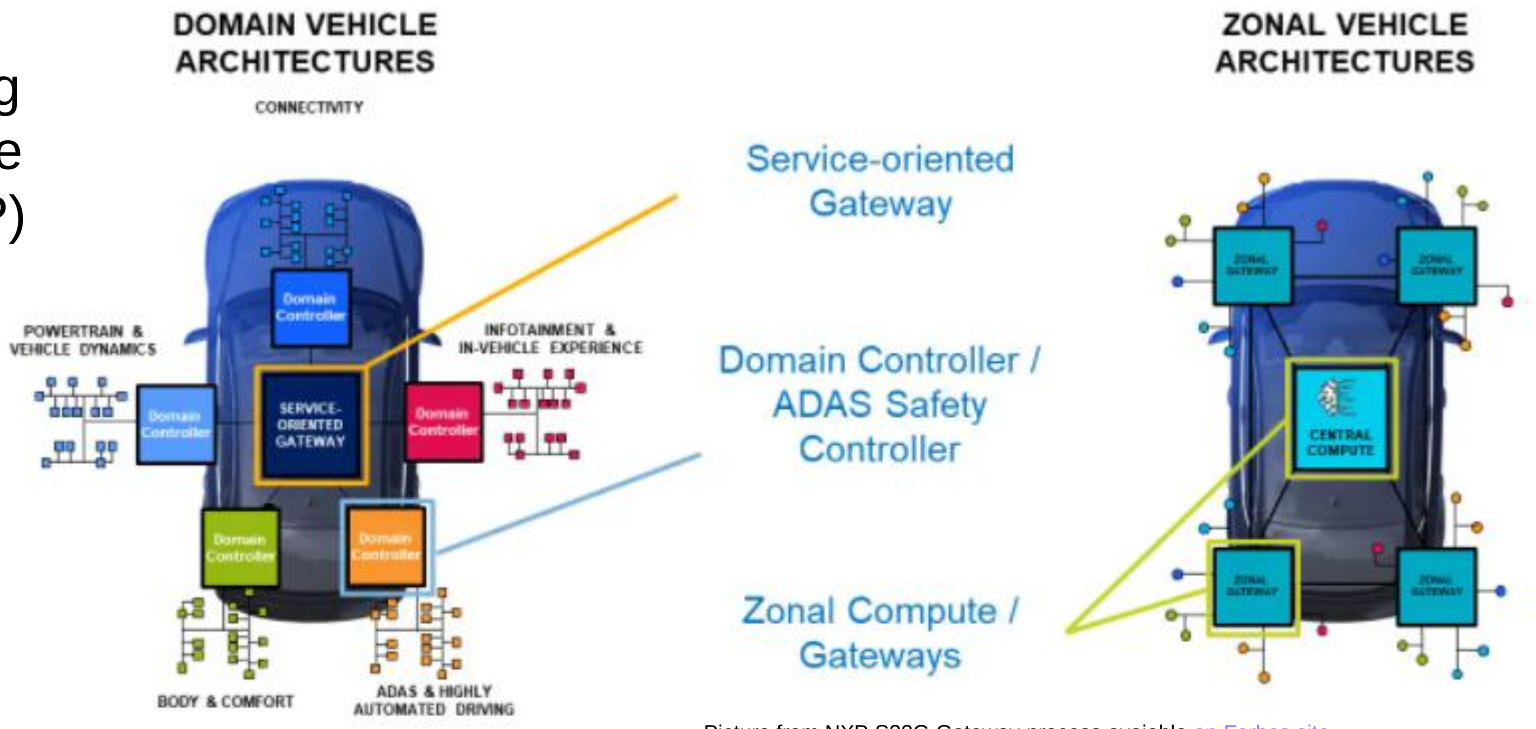
EDEN Team

Automotive Case Study
Ethernet Backbone using TSN

Continental Automotive

Trend for new Automotive Architecture

- Change of paradigme in **Electrical and Electronic Architecture**
  - High Performance Computing unit (HPC) connected to Zone Control Processing unit (ZCP) via Ethernet Backbone
  - Software Centric Approach (SOA concept)
  - New sensors (Camera/Lidar) for Autonomous Driving

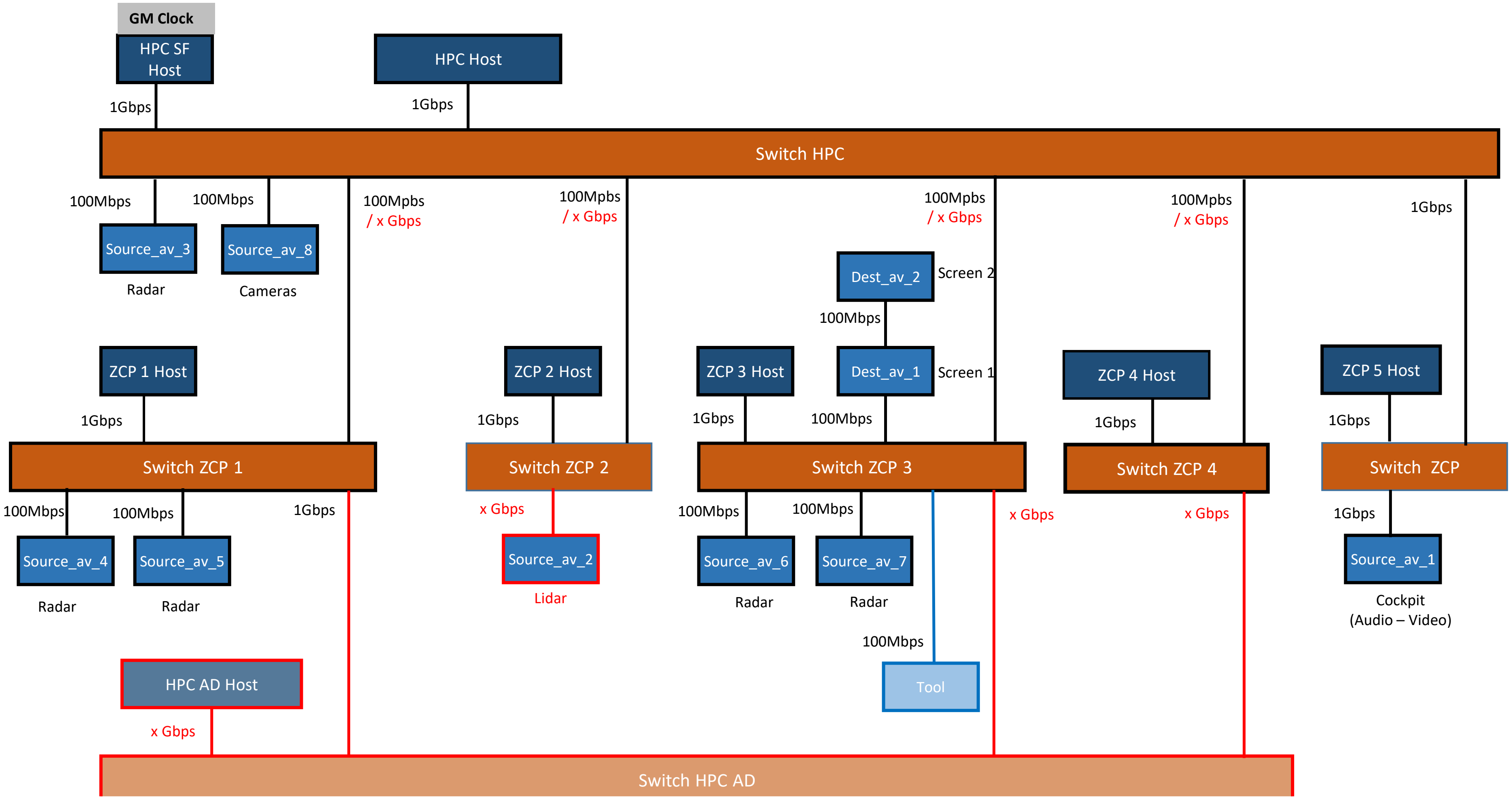


Picture from NXP S32G Gateway process avaiable on Forbes site

- Require <u>**Ethernet high bandwidth, time determinism and reliability concept**</u>

Case Study for Automotive Architecture

- **Architecture with variants : AD as an option** (red color)



Poc Platform only a subset of this architecture

Case Study for Automotive Architecture

- **Class Audio – Video flows Description (UDP)**
  - Class A audio 1.25ms periodic / 1.25 latency (blocks packaged)
  - Radar, Camera and Lidar periodic flow / 10ms and 33ms latency (buffering)
- **Flows Description - Control Command (UDP)**
  - **Service Oriented (SomeIP – Discovery/Subscription/Registery not yet considered)**
    - Event Flow 10ms to 1s worst-case period / 1 to 5ms latency,
    - Periodic Flow, Req/Resp Periodic flow from 5 ms / 1ms latency to 100ms / 10ms latency
  - **Legacy (CAN Message to Ethernet – Frame of 8 CAN message maximum)**
    - Very low latency frame (periodic 2 to 5 ms / 1ms latency)
    - Low latency frame (from 50 ms / 5ms latency to 500 ms / 50ms latency)
- **Flows Description – Best Effort (UDP – TFTP protocol)**
  - Diag. (Kbytes) and reprog. file (Mbytes) with transfer > 10Mbps / 200 ms latency

Traffic Shapping Hypothesis

Audio - Video

- Redundancy of Radar / Camera / Lidar frame for AD option
- CBS Shaping for buffered Frame (Radar / Camera / Lidar)
- Stereo streams (CBS)

Control - Command

- TAS for very low latency
- Priority (/ ATS) Very low or low latency ?

Best Effort

- Priority based for File Transfer

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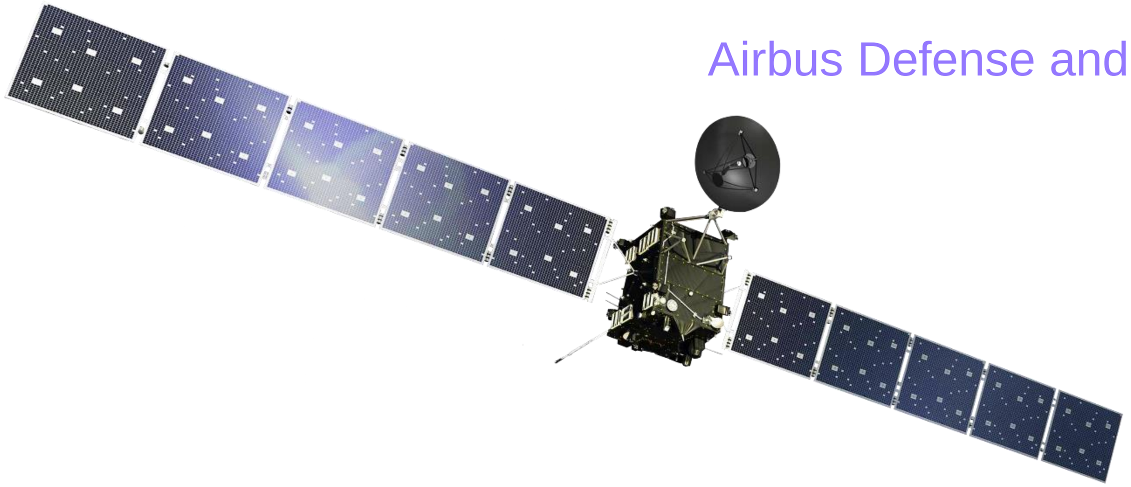
Space Case Study
Spacecraft avionics

Airbus Defense and Space



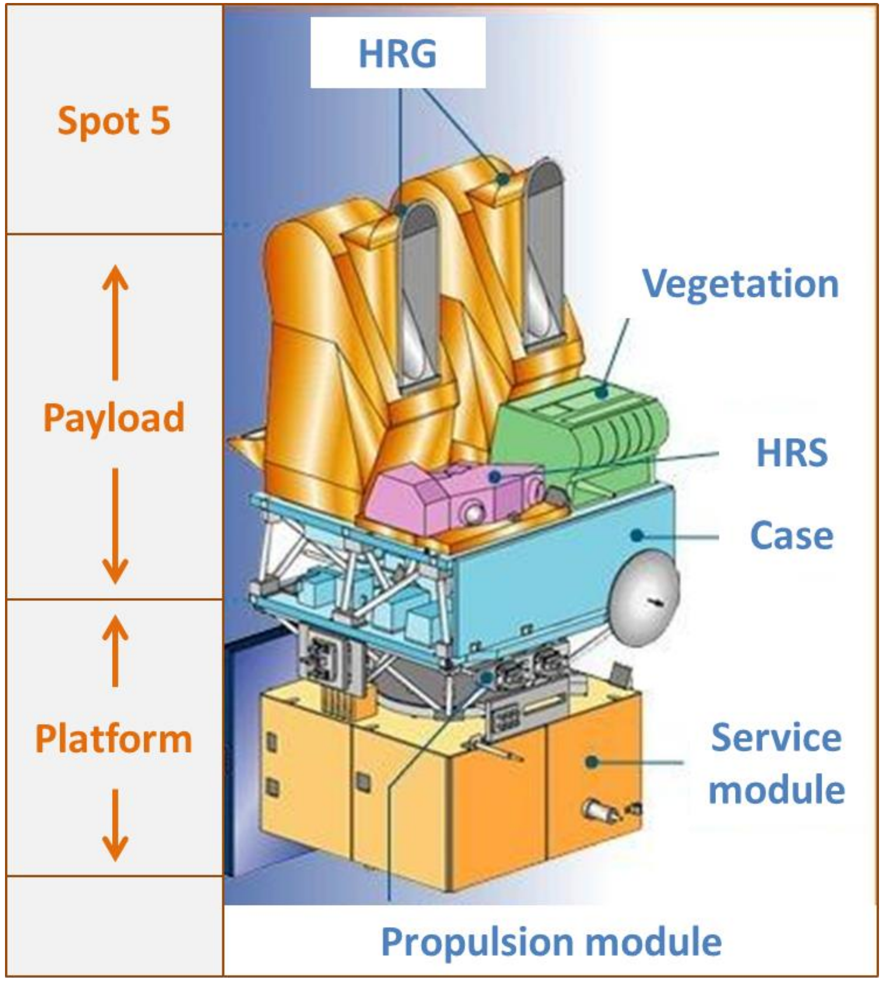
Spacecraft System

- **Payload** - ***High Performance Domain***
  - Repeaters/Transponders,
  Optical Payloads and image processing

  ⇒ **high data rates / soft real time**
- **Platform - *Time Critical Domain***
  - Attitude Control, Power Supply, Monitoring and Control of Payload,
  Telecommunication with ground

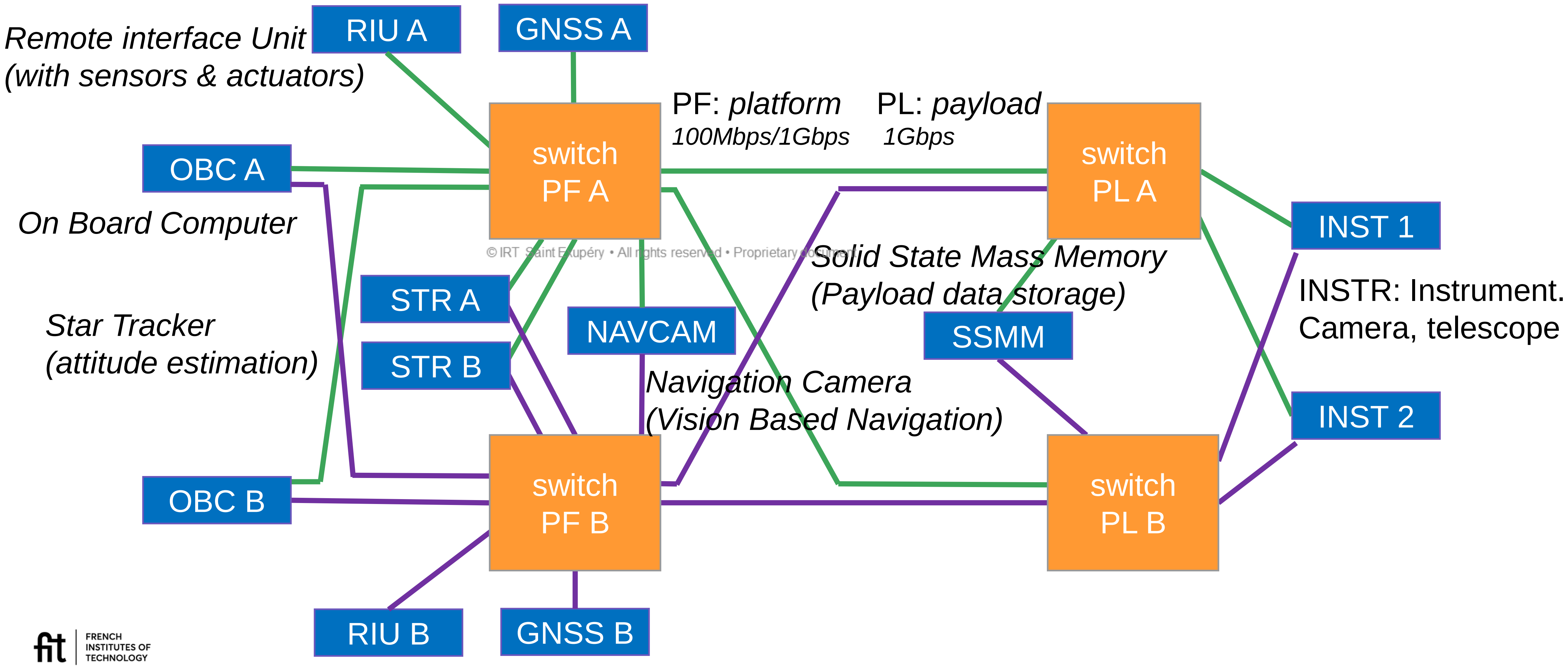
  ⇒ **low data rates / hard real time**

	Platform	Payload
MIL-STD-1553 1 Mbps	Command and Control Time synchronisation	Command and Control Time synchronisation
Spacewire 100 Mbps	Data transfer	Data transfer
Dedicated high bw datalink > 1 Gbps	N/A	Data transfer
dedicate discrete wire 1Hz, 8Hz	synchronization	synchronization



Transition to a unified network with TSN.

Proposed Topology

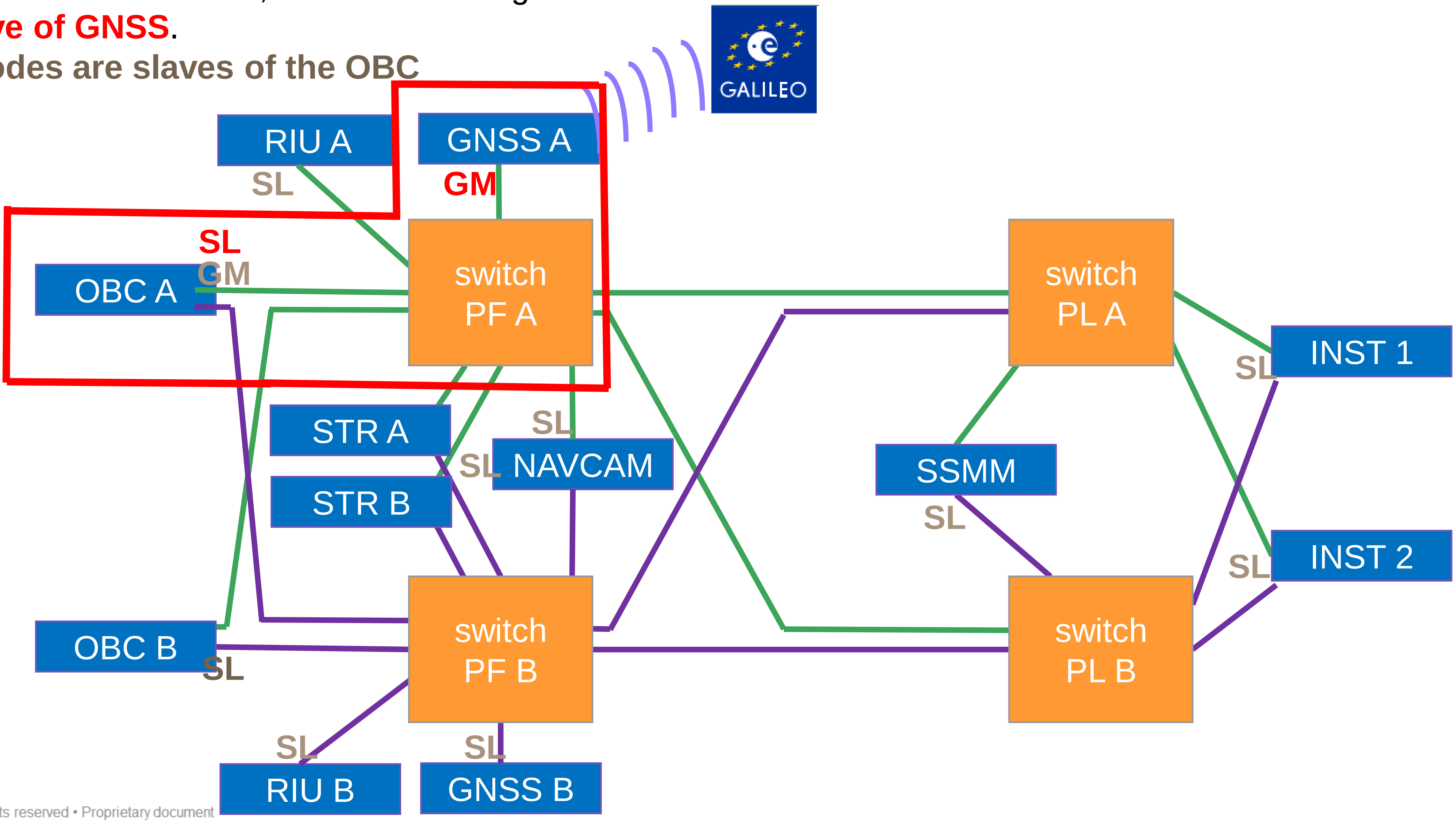


Time Synchronization Proposal

Two synchronization domains, no more PPS signal:

OBC is slave of GNSS.

All other nodes are slaves of the OBC



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Flows classification proposal

Command requests (CMD-REQ) (AOCS accurate low jitter): high frequency (8Hz), low jitter (1 µs), time window

AQUI (AOCS acquisition): high frequency (8Hz), bounded jitter (500 µs), time window

DATA (acquisition list): bounded delay between messages delivery

MEO: min delay between messages delivery (5ms)

HK + FDIR (Cyclic acquisition, RW management): deadline to the delivery (end of 8Hz or 1Hz cycle or AOCS acquisitions deadline)

VBN: high data rate, deadline to the message delivery (30Hz)

Instrument: very high data rate

no best effort with potential message drop identified so far.

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Traffic Shapping Hypothesis

Platform Command and control

- Redundancy of all nodes and pathes
- TAS for platform low latency and low jitter (AOCS)
- Static priority for others

Payload

- Static priority
- Urgent asynchronous messages (CBS ? TAS ? ATS ?)

Best Effort

- Priority based storage of NAVCAM images in SSMM

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Digital Audio Use case for TSN

Airbus Commercial Proposal

Preliminary

This presentation aims to introduce a specific use case, considered as relevant in AIRBUS Commercial, to be study in EDEN project.

Internally Airbus Commercial, activities are on going on “Audio digitalisation”, and it has been identified that some TSN features could be of interest to improve audio services and quality.

The following slides provide information to set up a practical use case, pointing key items to be evaluated against TSN mechanism

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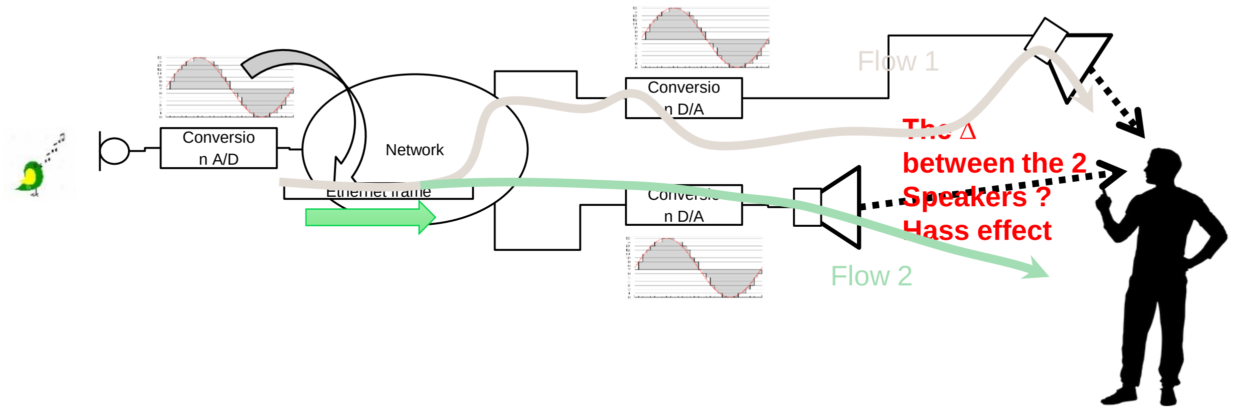
Sending audio on a network vs problem of latency and jitter



Signal Path	Latency aspect	
	Flow 1	Flow 2
A/D Conve	$t_{A/D}$	$t_{A/D}$
Network	t_{Net1}	t_{Net2}
D/A Conve	$t_{D/A1}$	$t_{D/A2}$
Δ latency	$(t_{Net1} - t_{Net2}) + (t_{D/A1} - t_{D/A2})$	

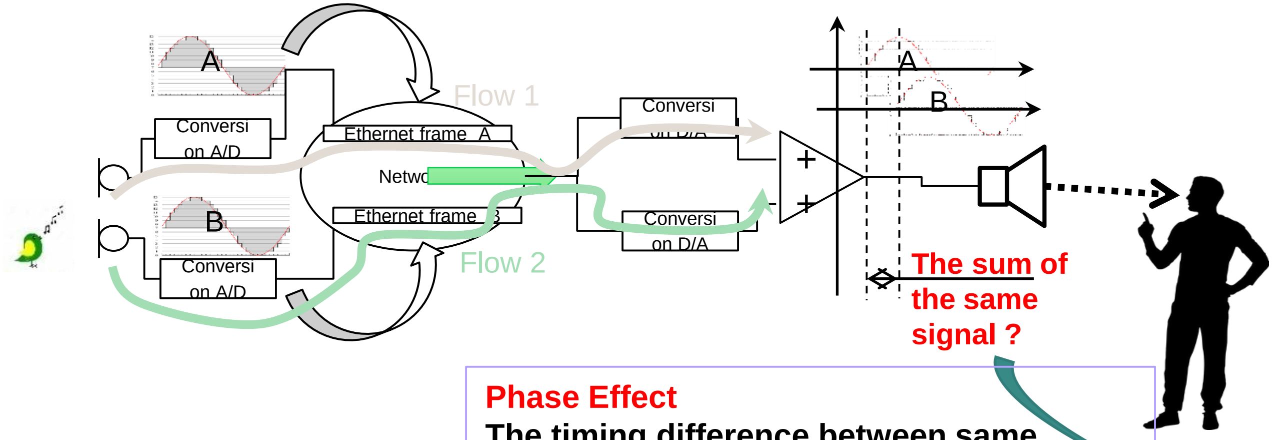
HAAS EFFECT

Δ < 2 ms: Perception of one sound . Localization between the lead and lag sound.

2 ms < Δ < 5 ms Perception of one sound. Localization of the leading sound.

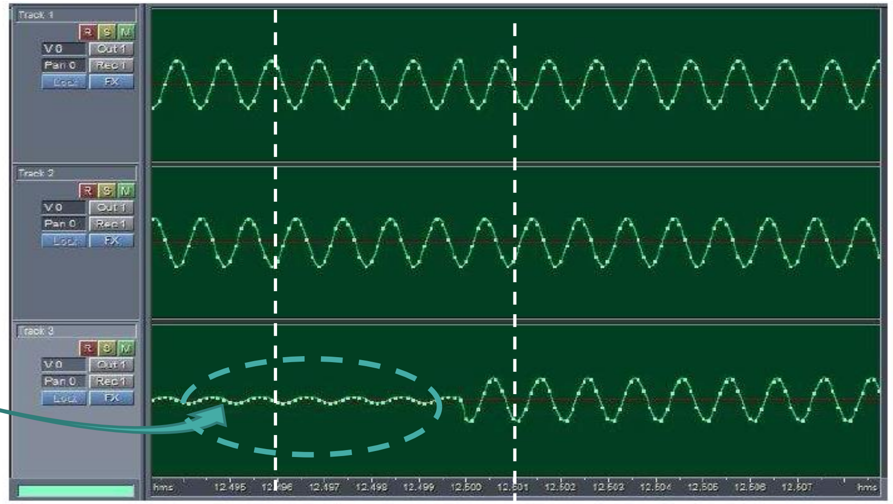
5 ms < Δ < 20 ms less discrimination of the location of the lagging sound

Δ > 20 ms The second signal is perceived as a separate event apparition of audio phenomena.



Phase Effect

The timing difference between same source can be detected by the listener even for very small latencies down to 6 µs



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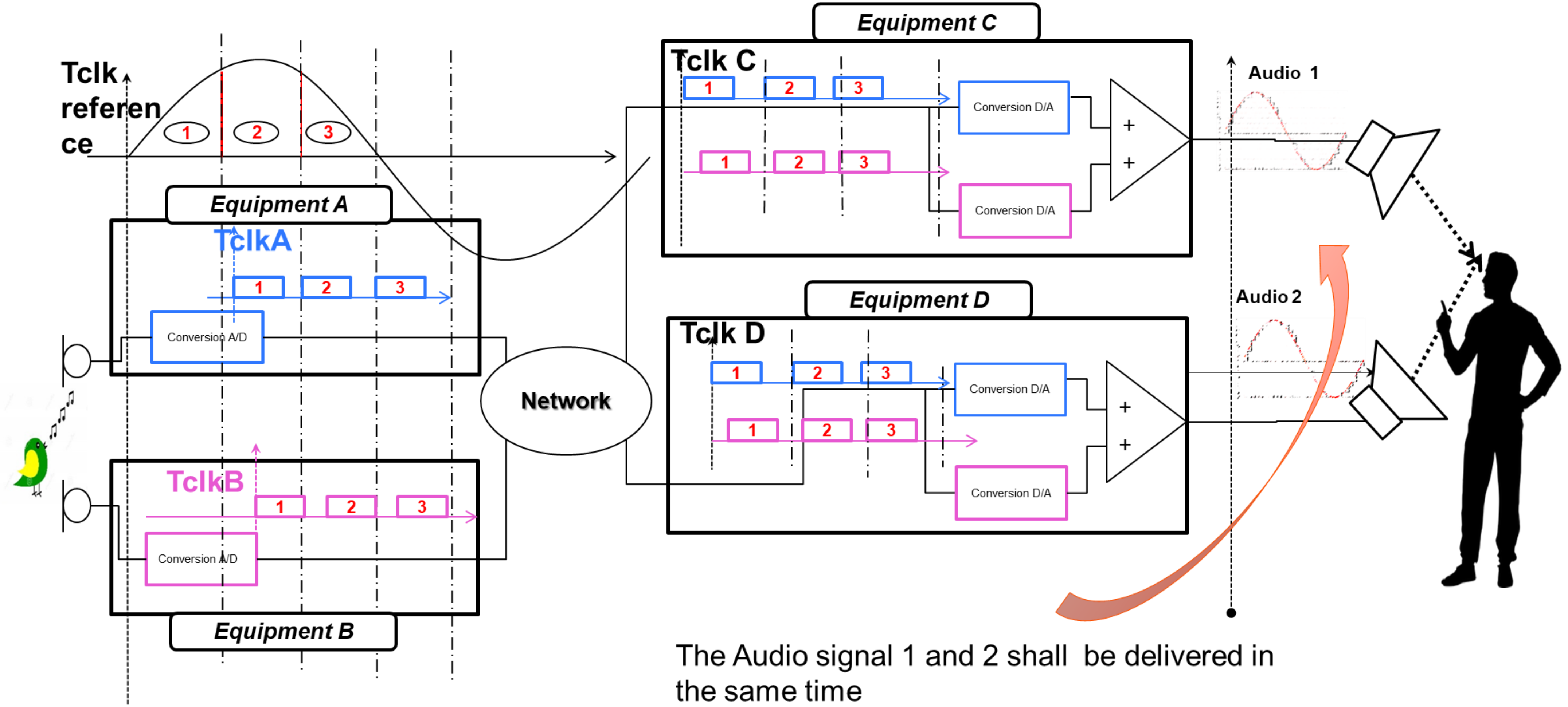
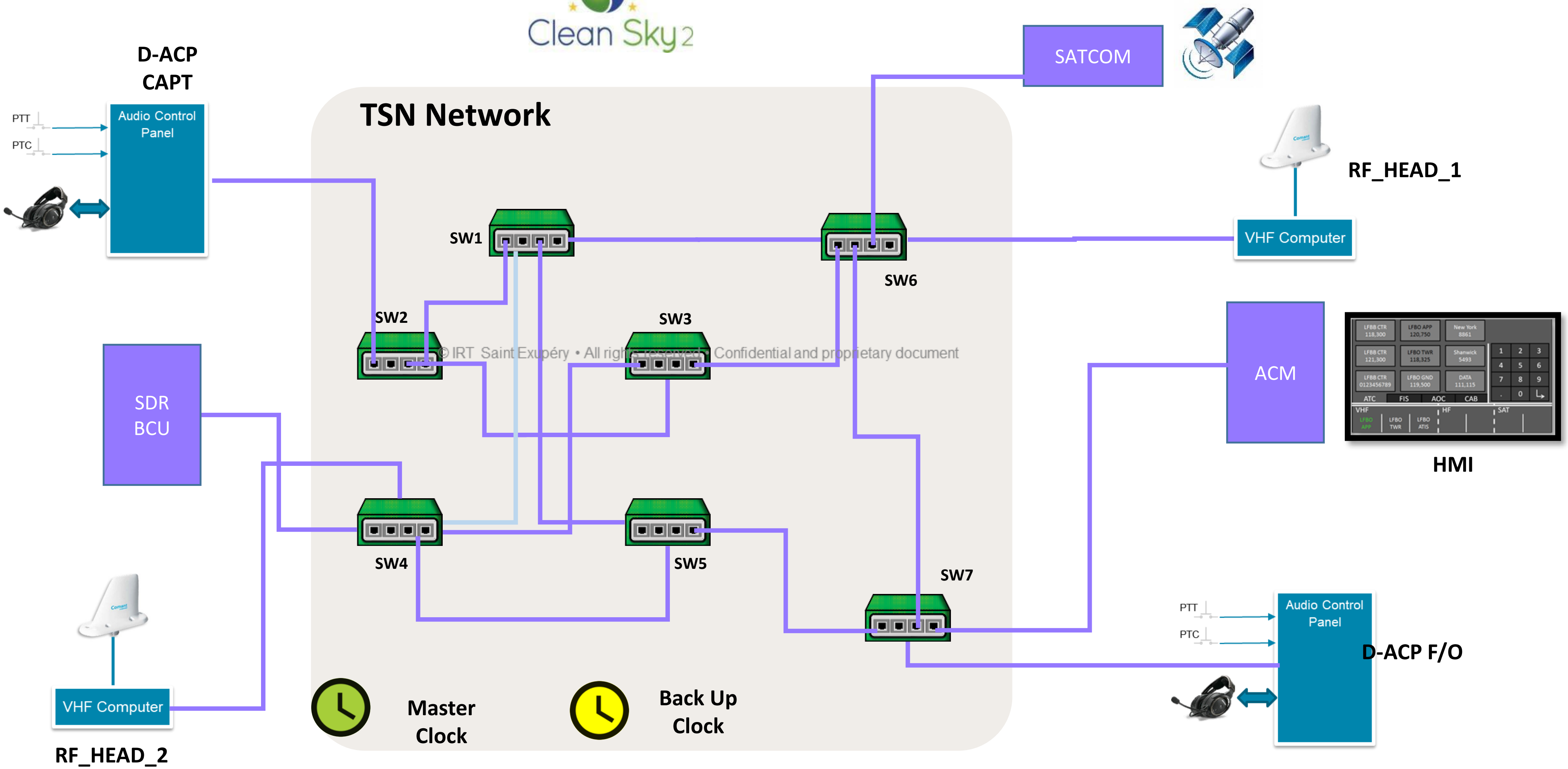
The solution by the Synchronization (1/2)



The Audio signal 1 and 2 shall be delivered in the same time

Architecture for digital audio cockpit : (Clean Sky 2 project)



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Hypothesis on the network

- All dataflow (audio and command) will be sent in multicast mode
- Data synchronization will be done at applicative level
- RTP protocol will also be used (upper UDP level) as network protocol for audio frames delivery
- Digital ACP samples the voice at 16kHz with 16 bits per samples
- Synchronization between real time publishers and subscribers is required to minimize audio noise due to dropped or added samples and to meet the RTCA DO-214A differential delay requirement. The Audio System shall use PTPv2 as per IEEE 802.1AS
- All data should be timestamped with a precision of 1µs. Time stamp should be gotten prior to send UDP packets. Master clock is the reference time
- Data should be continuously sent. As such, when channel is silent (PTT at 0), Null audio packets will be sent (Payload at 0). It will help to monitor that producer or network are functional. From aircraft network design point of view, not sending nulls would not save any bandwidth in final application because network calculus will have to consider the worst case, i.e. always sending.

Traffic Shapping Hypothesis

Audio

- Redundancy of information
- TAS or CBS Shaping

Command

- Redundancy of information
- TAS or CBS Shaping

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TOOL FRAMEWORK

EDEN Team

POC Platform for characterization

Platform overview

Platform components for synchronization and traffic analysis available

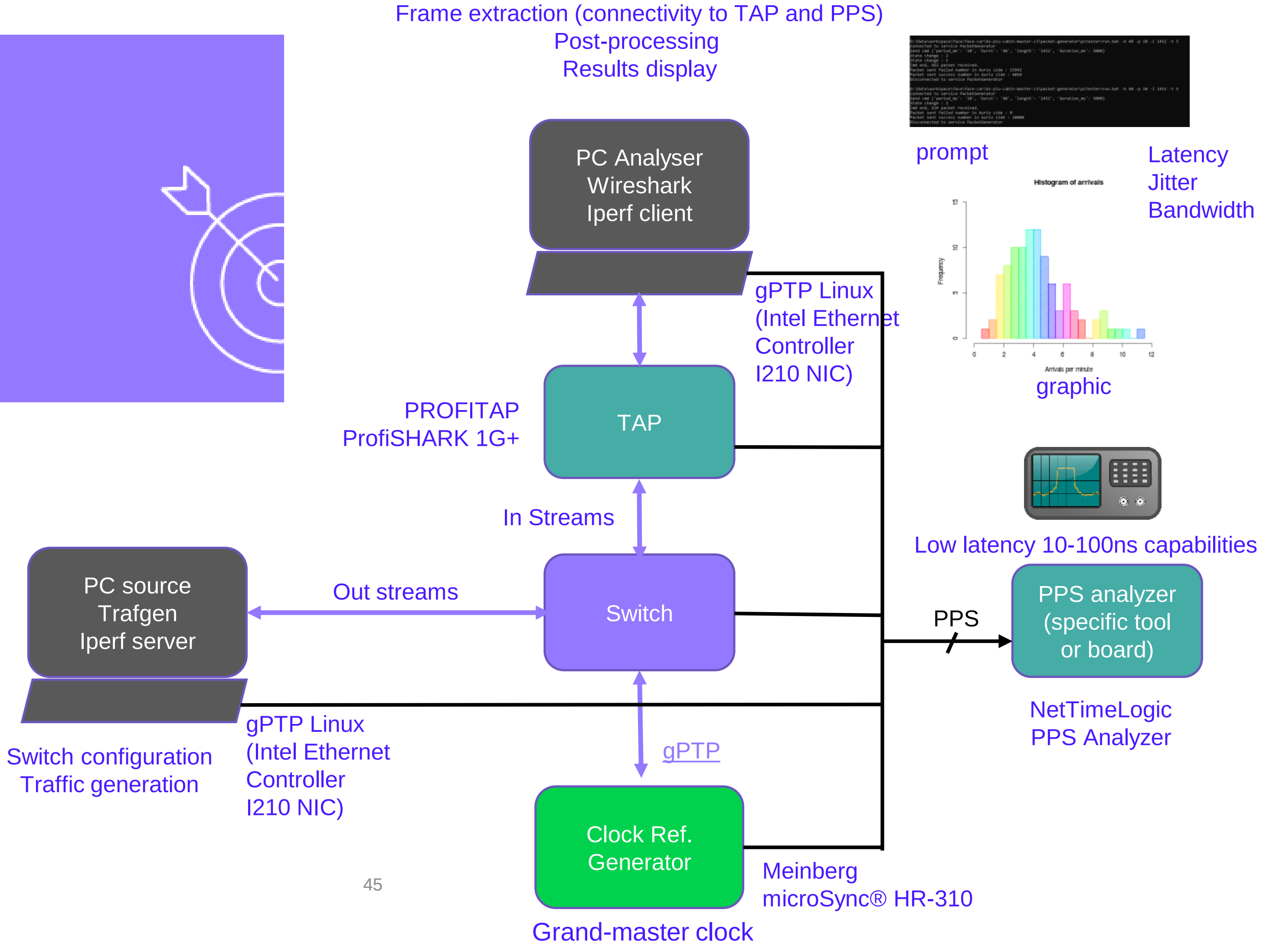
High quality Synch. reference

Automated platform

Full coverage of TSN services

Validation on one commercial switch SoC

Base for PoC platform set-up



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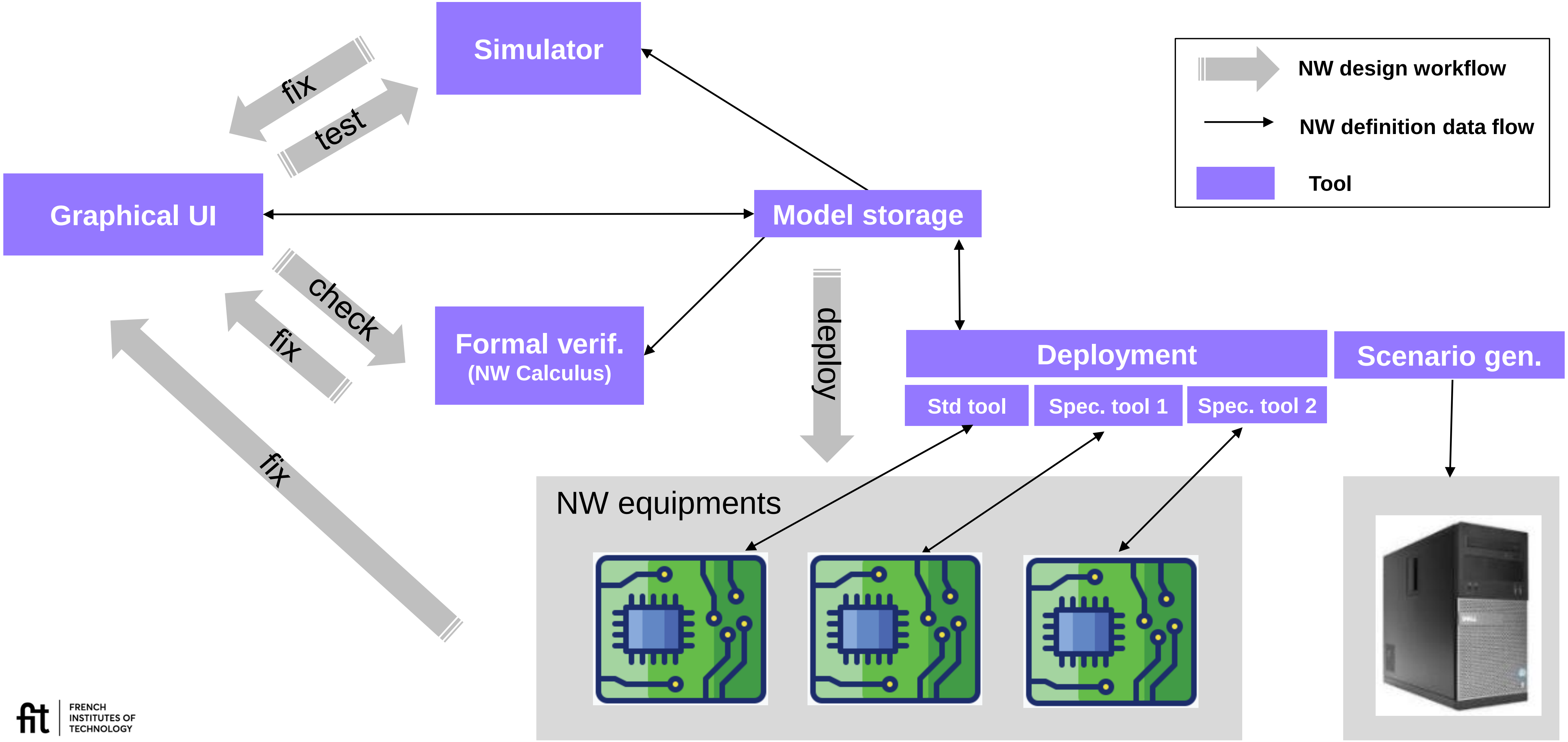
Network design

Design Workflow



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Network design toolset

Tool overview

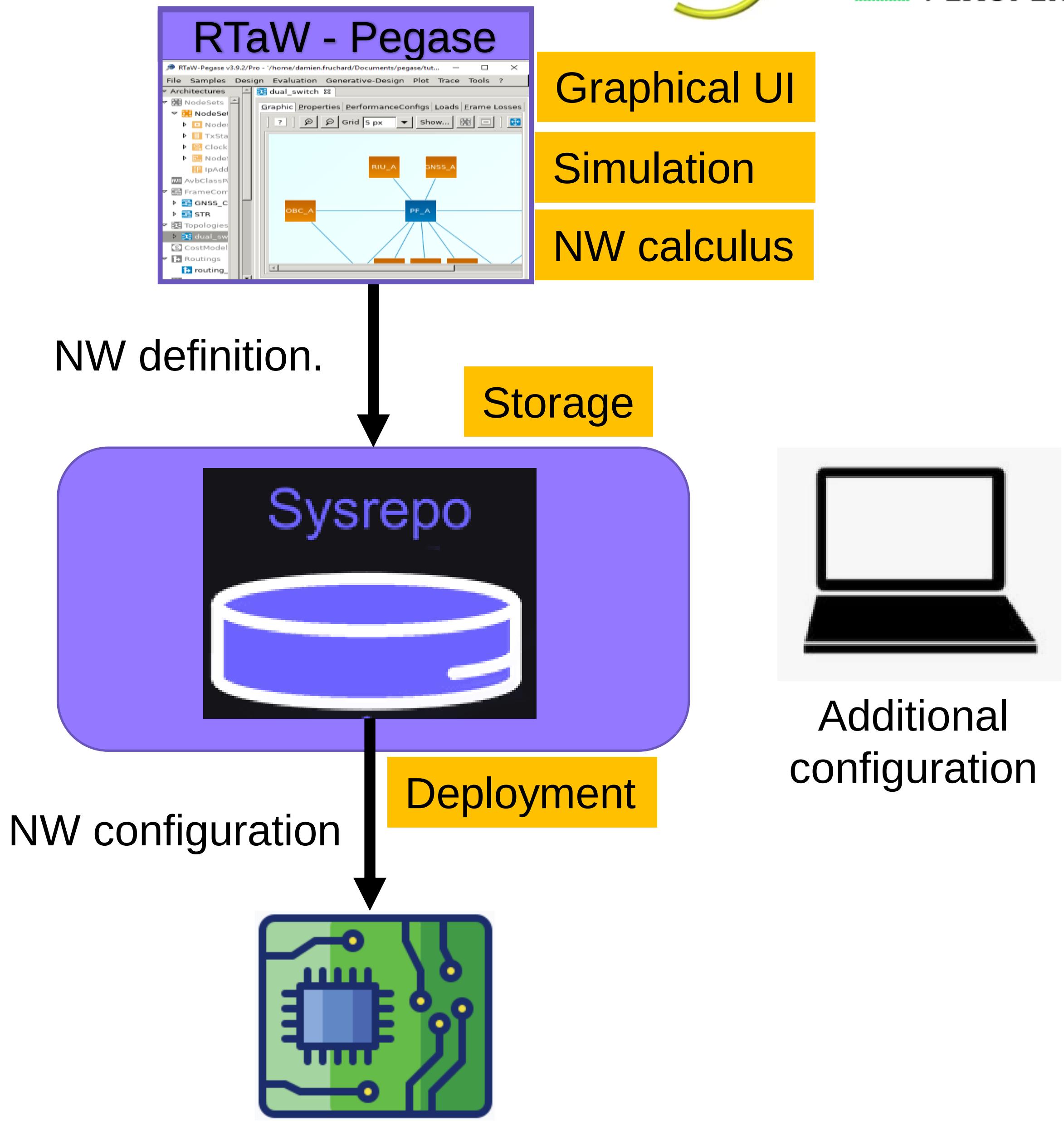
Platform for design, and configuration of network

Sysrepo Database

- **Uses YANG Data Model**
- **Interface plugins**
- **NETFCON Ready**

Automated conf. platform

Targets full coverage of TSN configuration



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PERSPECTIVES

EDEN Team

EDEN Project Outcomes

- ***Define the use of TSN standard for temporal determinism and redundancy (with mixed criticality)***
  - ***Guideline for configuring network service*** in accordance with safety and availability requirement
- ***TSN profile standardization proposals***
  - Proposal to standardization boby (IEEE and ECSS)
  - ***Hardware requirement specification*** *for Switch / End-point COTS component*
- ***Toolset for development and certification of Embedded Network Architecture***
  - Simulator, TSN configuration generator and formal verification (Network Calculus)
- ***Electrical and Electronic Architecture Proof of Concept Platform***
  - Operational demonstrator and ***Platform for network application benchmarking***
  - Ground for others research projects

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Questions

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