WELCOME

TiM

Testing & Training in Motion

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General Introduction

Johnny PAPPAS

EVP & CTO

Safran Data Systems

Agenda

Testing & Training in Motion

PART 1

SAFRAN

Safran, an Industrial High Technology Group

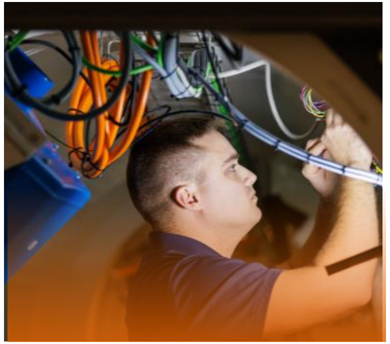
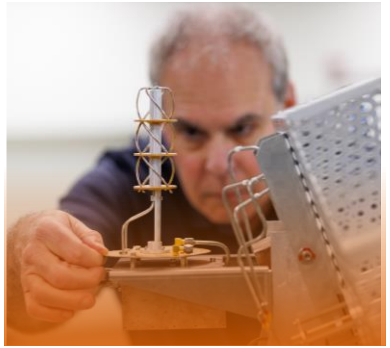
83,000
employees

€19.0
billion in revenues in 2022

125 years
of history: the oldest aerospace manufacturer in the world

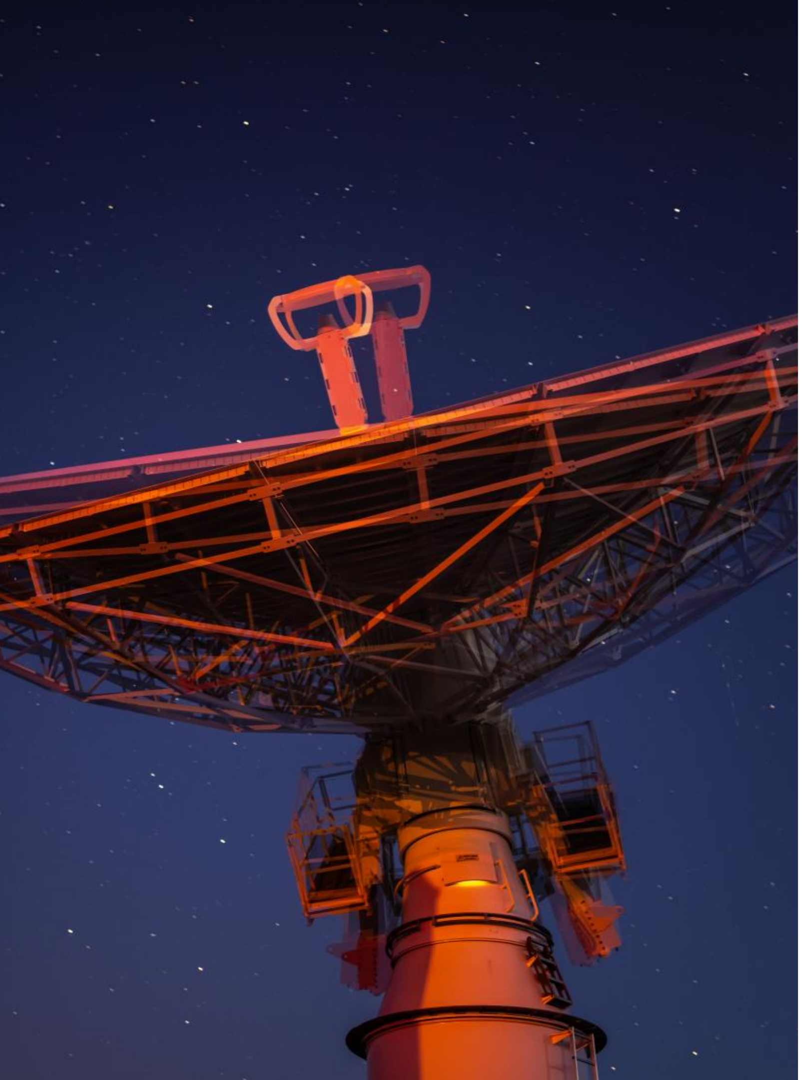
No.3
aerospace company worldwide (excluding aircraft manufacturers)



Our mission:

making aviation more sustainable
and the world a safer place



PART 2

SAFRAN SPACE

Safran Electronics & Defense, the Space Division & its affiliates

Testing & Training in Motion

Safran Electronics & Defense

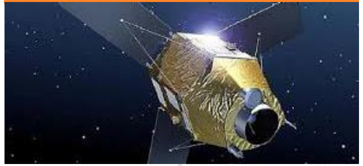
Defense

Avionics

Navigation & Timing

- Navigation
- Timing solutions
- Clocks
- Simulation

Space



Finance, Sales & Marketing, Communication, HR, Strategy

Syrlinks

Safran Reosc

Safran Spacecraft Propulsion

Safran Data Systems

SAFRAN

Safran Space – U.S. Space Sovereignty & Dominance

Deterrence
- Tracking stations
- Telemetry receivers

Access to Space
- Vehicles instrumentation
- Tracking stations
- Telemetry receivers

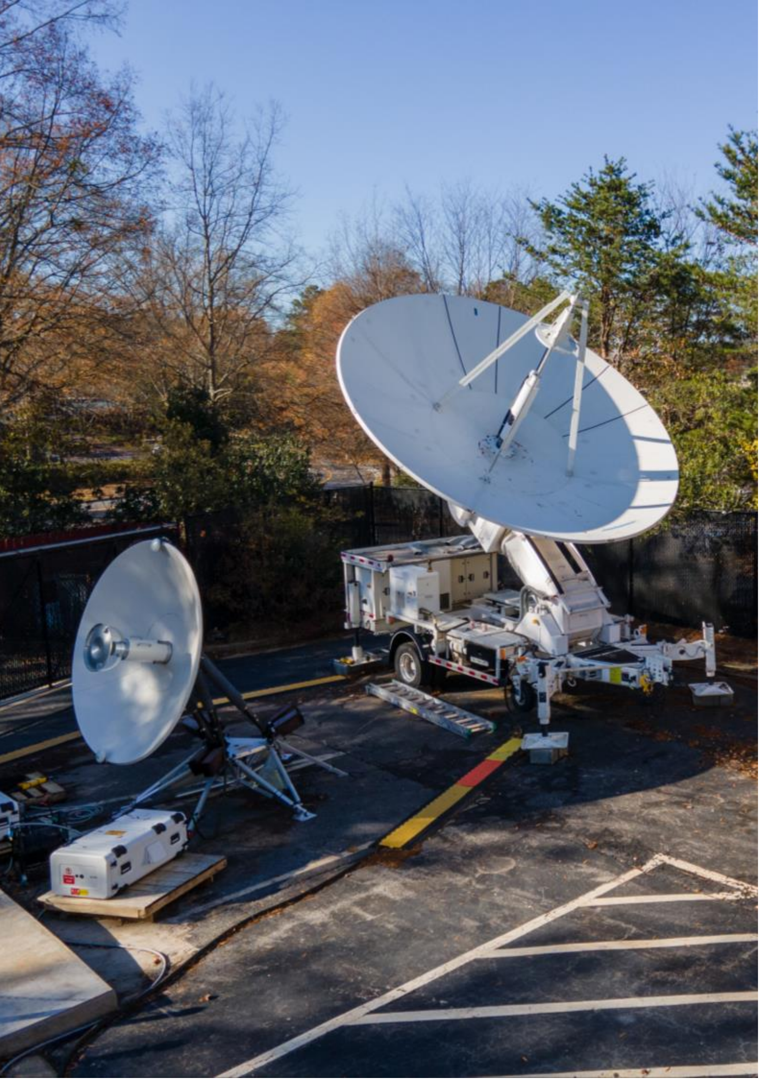
Space-based ISR
- Precision oscillators
- Tracking stations
- Telemetry & control modems

Coms & PNT
- Attitude sensors
- Control modems
- Timing solutions
- Anti-jamming systems

Space Awareness
- Ground sensor service & analytics

Customers who trust our US division

& their contractors



PART 3

SAFRAN DATA SYSTEMS

Testing & Training in Motion

SAFRAN

Safran Data Systems, Inc., the U.S. subsidiary

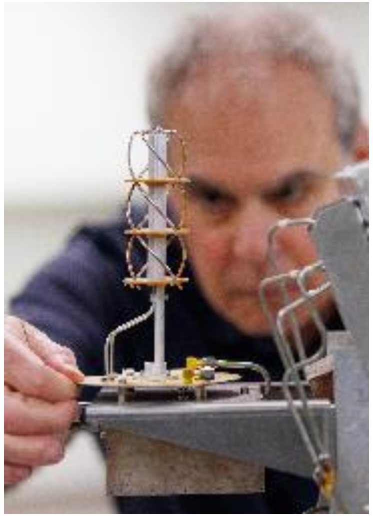
Testing & Training in Motion

- Cleared Defense Contractor
- FOCI Company
- Facility Clearance to the Secret Level
- Special Security Agreement (SSA)
- AS9100 Certification

50+
employees

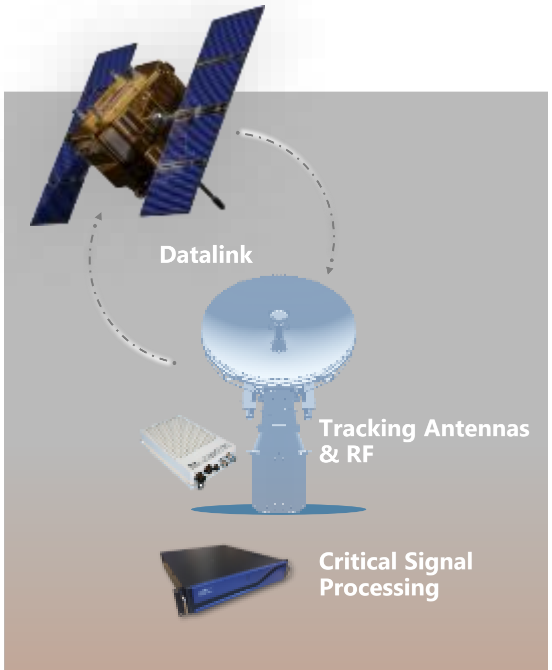
40+
years serving DoD / USG

$50
Millions annual revenues

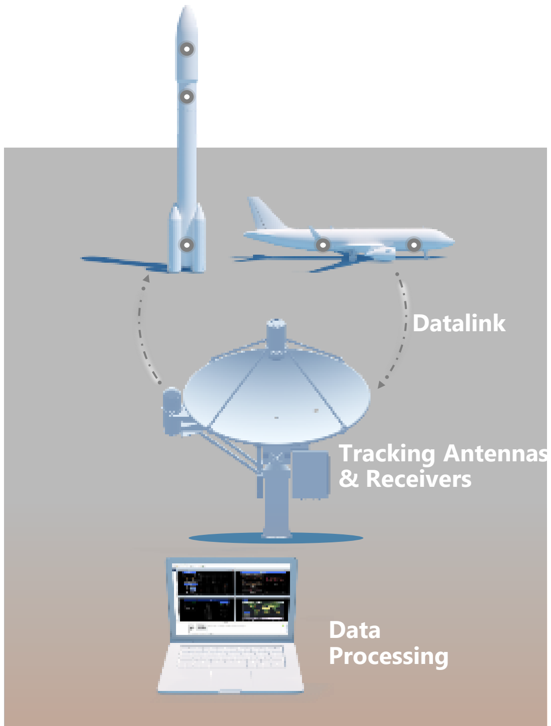


SAFRAN

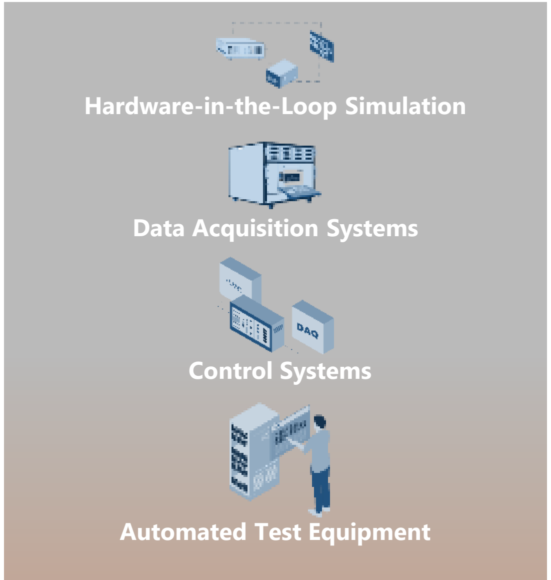
Safran Data Systems: At a Glance



Connecting Space



Enabling Aerospace Testing and Information Systems

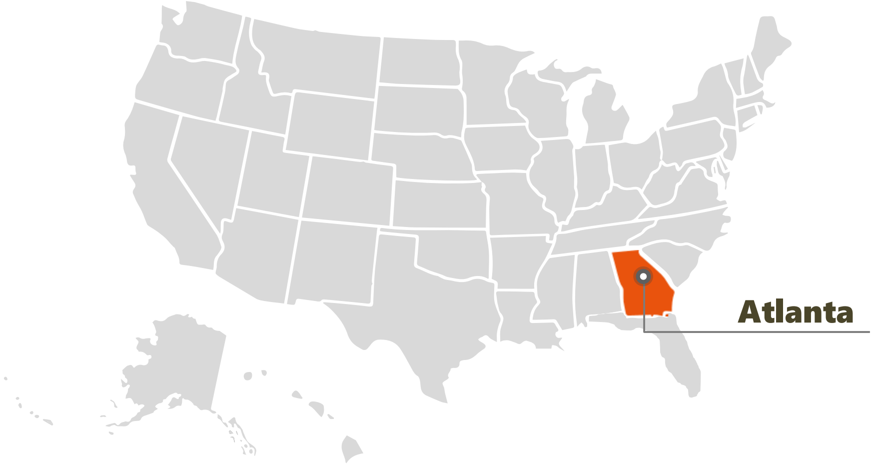


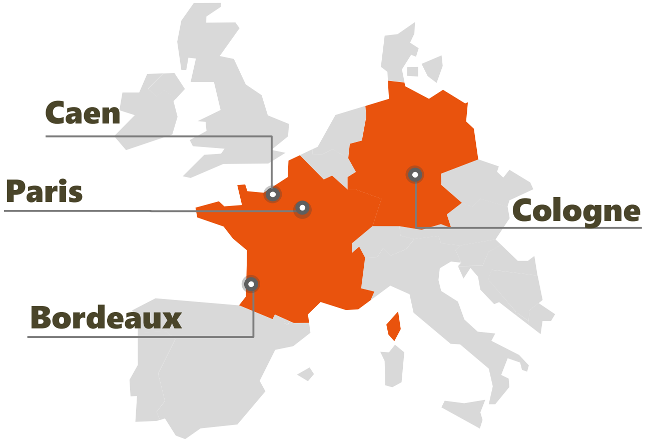
Simulation and Testing

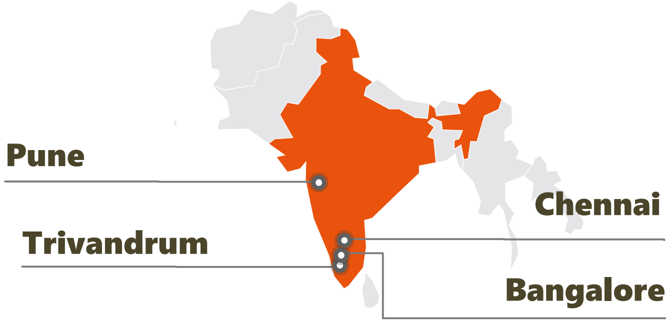
SAFRAN

Safran Data Systems: Our Facilities

Testing & Training in Motion







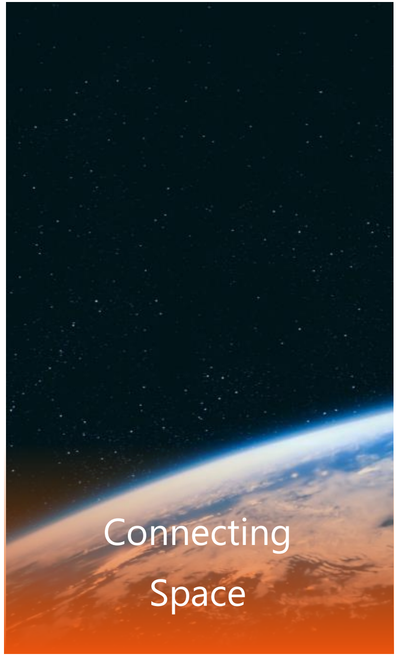
~850 EMPLOYEES WORLDWIDE

NETWORK IN 40 COUNTRIES

SAFRAN

Worlwide Leader

Leader in Instrumentation for Testing, Telemetry, Mission Data Management and Communications for Space



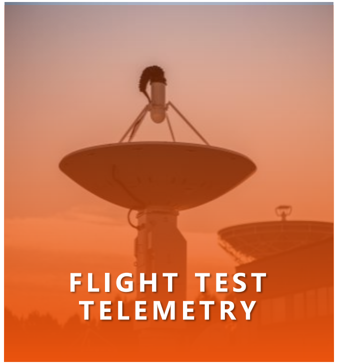
Our Missions: *Enabling Aerospace Testing*

01
Turnkey systems for full platform certification

02
Equipment for weapon system upgrade testing

03
Smart solutions for small platform testing

04
Versatile hybrid signals & video acquisitions



01
COTS and innovative datalink solutions

02
Full range of fixed and mobile tracking antennas

03
Comprehensive telemetry and signal reception / recording / display suite

01
Ruggedized instrumentation equipment for missile

02
Missile and weapon check-out / testing

03
Across-the-board tracking systems for telemetry range reception and safety

01
Flexible and scalable instrumentation with signal conditioning & video acquisition

02
Upper atmosphere environmental-proof instrumentation & telemetry

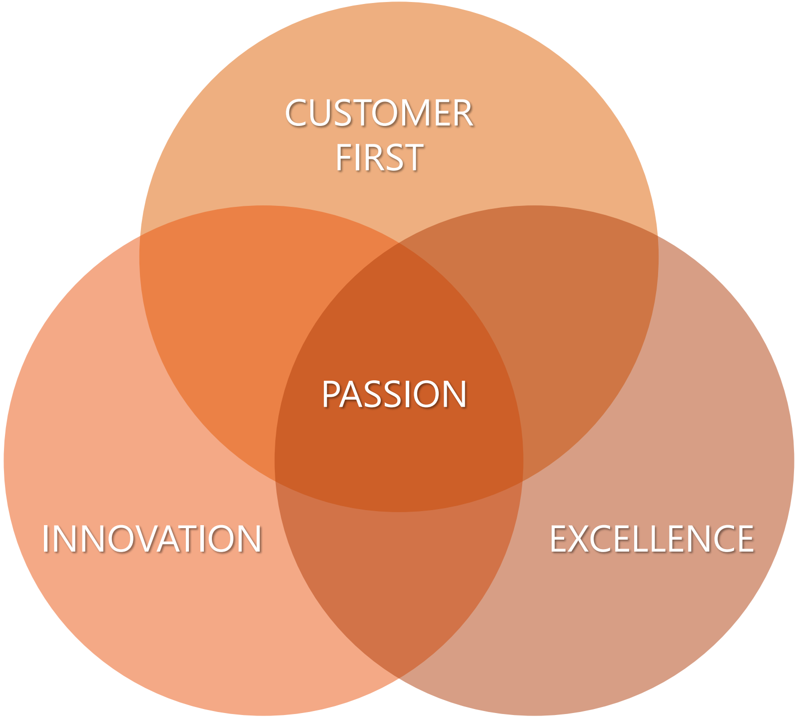
03
Ad-hoc compact ground receiving & display solution

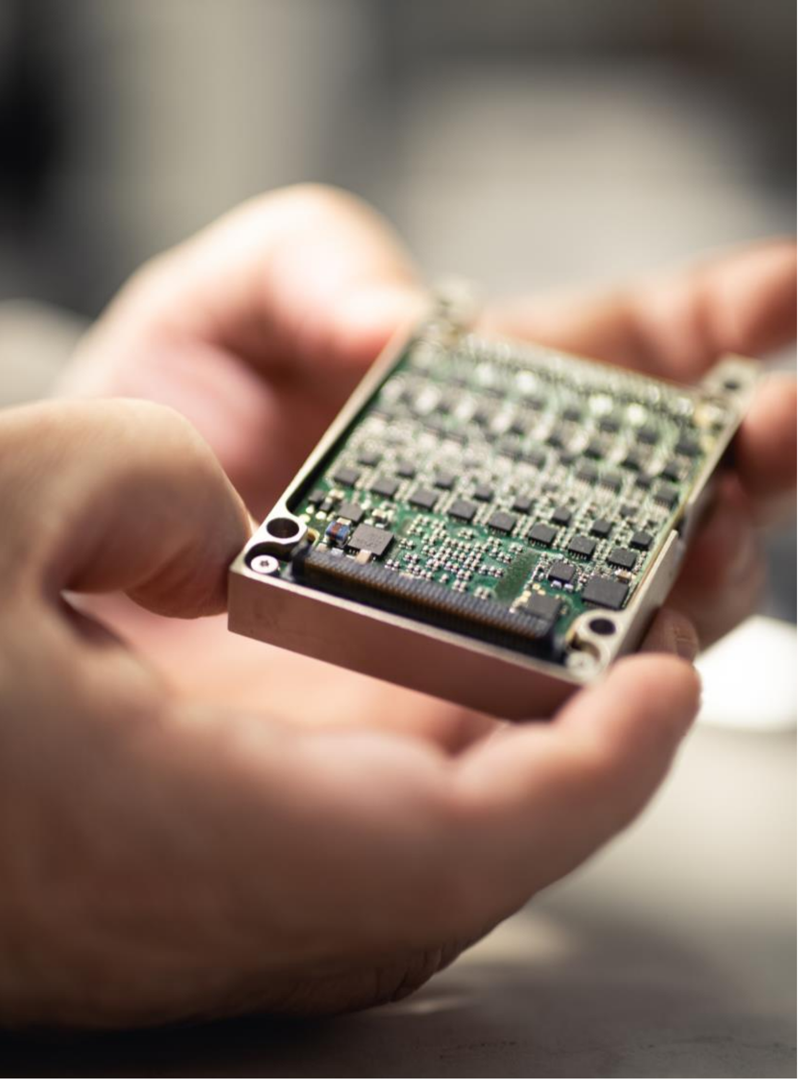
01
Data & Video Recorder / Server for ISR, search & rescue and mission debriefing

02
Pilot training

03
Flight data recorders

Our Vision & Values





Testing & Training in Motion

PART 4

TESTING & TRAINING IN MOTION

SAFRAN

Testing & Training
in Motion

Collaborative innovation, knowledge exchange and networking about flight testing (airborne & ground segments) and launch vehicle avionics, telemetry & safety

Since 2018

SAFRAN

Testing & Training in Motion

11

Testing in Motion events organized since 2018

+700

Attendees since 2018

Since 2018

Collaborative innovation

Knowledge exchange

Networking about flight testing (airborne & ground segments) and launch vehicle avionics, telemetry & safety

Testing & Training in Motion

Expand your knowledge by following our training and earn Continuing Education Units (CEUs)

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PART 5

TESTING & TRAINING IN MOTION - AGENDA

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Agenda

Testing & Training in Motion

AM	8:00 - 8:30	REGISTRATION & WELCOME COFFEE	
	8:30 – 8:45	**GENERAL INTRODUCTION**	
	8:45 - 10:00	COFFEE BREAK / HANDS-ON SESSIONS	**HANDS-ON SESSIONS** • HOW TO GET RID OF WIRES FOR YOUR FTI? • DISTRIBUTED INSTRUMENTATION SYSTEMS, LEVERAGING NEW TECHNOLOGY IN YOUR SYSTEM ARCHITECTURE • OBP MODULE – MULTILATERATION PROCESSING • BEST SOURCE SELECTOR TO IMPROVE THE TELEMETRY RECEPTION IN REALTIME • FIBER BRAGG GRATING (FBG) • CYBERSECURITY FEATURES ON THE MDR-GTS • THE RSR-RF-200, THE ULTRA-WIDEBAND RECORDER THAT CAPTURES AND REPRODUCES YOUR ENTIRE RF TELEMETRY SPECTRUM ** Break during lunch time.*
	10:00 – 11:00	**INTRODUCTION: WIRELESS INSTRUMENTATION**	
	11:00 – 12:00	**TRAINING: FIBER SENSING**	
	12:00 – 1:00	**TRAINING: ON-BOARD PROCESSING: HOW AND WHY PROCESSING IS NOW MANDATORY IN YOUR FTI?**	
PM	1:00 – 2:00	LUNCHEON / NETWORKING	
	2:00 – 3:00	**TRAINING: RANGE OF THE FUTURE, HOW THE RANGE ARCHITECTURE IS EVOLVING?**	
	3:00 - 4:00	**TRAINING: IRIG 106 CHAPTER 7: PACKET TELEMETRY DOWNLINK-UNDERSTANDING THE STANDARD**	
	4:00 - 4:15	COFFEE BREAK / HANDS-ON SESSIONS	
	4:15 – 4:30	**WRAP UP**	
	5:00 - 8:00	SOCIAL EVENT – T&P Tavern	

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Introduction Session

Wireless Instrumentation

This introduction to wireless instrumentation focuses on the relevant example of helicopters.
What are the main specifics of the FTI for an helicopter. How a fully wireless system could ease installation and operations.
In addition several options will be presented to make benefit of this wireless solution to connect any third party remote devices onto the rotor head!

TRAINING ROOM: 10:00 - 11:00 am

Training Sessions – Earn CEUs by scanning QR codes!

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Fiber Sensing

Learn about the various Fiber Sensing technologies with a focus on Fiber Bragg Grating (FBG). See how it can favorably replace legacy temperature, strain or pressure sensors on airborne application, but also how you can combine heterogeneous sensor measurement together.

TRAINING ROOM: 11:00 - 12:00 am

Range of the Future, how the range architecture is evolving

DoD test ranges, FT centers and space ports are facing emerging challenges such as the higher rate of flights / launches, increase of downlinked Telemetry or the testing of platforms going further and faster. This training will provide an overview of the current Telemetry range architecture, and then touch on the various solutions, either already available or under development like AESA antennas, Space based Telemetry, Ultra-wideband RF recording, etc.

TRAINING ROOM: 2:00 – 3:00 pm

On-Board Processing: How and why processing is now mandatory in your FTI?

From saving bandwidth to calculation result in real-time, processing as near as possible of the measure brings a new level to your FTI. Interconnected devices, Ethernet synchronized network, powerful embedded chip allows the possibility to begin the data analysis way before its transmission to the ground. Thus it speeds up the test campaign and enhances the safety of the pilot plus his test vehicle.

TRAINING ROOM: 12:00 - 1:00 pm

IRIG 106 Chapter 7: Introduction and Fundamentals of IRIG 106, Chapter 7, Packet Telemetry Downlink

This short course focuses on providing the basics of IRIG 106 Chapter 7 Packet Telemetry Downlink. You will learn how data packets are transformed into telemetry packets and a Chapter 7 telemetry stream is constructed. In addition, an actual hardware and software demonstration will address the various aspects to program and establish an end-to-end implementation of a Chapter 7 Packet Telemetry Downlink.

TRAINING ROOM: 3:00 - 4:00 pm

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Hands-On Sessions

Testing & Training in Motion

How to get rid of wires for your FTI?

Let's demonstrate a way to replace wires for power supply, data transfer and synchronization of your FTI system. What are the impact on performances in comparison to a wired system?

The RSR-RF-200, the Ultra-Wideband recorder that captures and reproduces your entire RF Telemetry spectrum

The demonstration focuses on the RSR-RF 200, the latest ch10 compliant ground telemetry recorder from Safran capable of recording and reproducing two channels with up to 200MHz of continuous bandwidth in L, S and C-band TM spectrum.

Distributed Instrumentation Systems, leveraging new technology in your system architecture

Introduction to our distributed system capabilities including DAUs, recorders, switches and software. Get an overview of how this technology can simplify your installations data management, and improve setup times.

Best Source Selector to improve the Telemetry reception in Real-Time

This hands-on session will highlight the Best Source Selector (BSS) solution developed by Safran, able to accept multiple input streams in various formats, i.e. analog baseband, PCM data/clock and TMoIP packets (IRIG-106 ch10 or IRIG 218-20). It will also show the time alignment to compensate for the different latencies among those sources and the different criteria available to perform the source selection : Frame Synchronizer, Majority vote and Data Quality Metric : DQE/DQM.

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Hands-On Sessions

Testing & Training in Motion

Fiber Bragg Grating (FBG)

Come and see a live demonstration of a highly compact modular FBG interrogator integrated into an XMA stack mixing together legacy and Fiber Sensing measurements.

OBP module – Multilateration processing

OBP module, the answer to On-Board Processing 's challenge. Synchronization and processing latency are two prerequisites for FTI on-board processing, here through the example of multilateration calculation, we will demonstrate the OBP capacity to process data from several data acquisition unit.

The multilateration is the capacity to locate a source of emission thanks to wave's time-of-arrival from at least three well-synchronized receivers (trilateration) and location equation resolution.

Cybersecurity features on the MDR-GTS

Discover our latest cybersecurity features including encryption capabilities, key management, and Data-At-Rest.

Aircraft Information Systems

A full range of rugged, versatile mission/avionics video and data recorders/servers and associated equipment and services for video and data acquisition, processing, storage, exploitation and dissemination applications for on board operation manned or unmanned ground, air and sea vehicles.

Free Social Event

5:00 to 8:00 pm

T&P Tavern
221 W Lancaster Ave, Fort Worth, TX 76102

Ask for your wristband!

PART 6

PRESENTATION OF THE TEAM

Testing & Training in Motion

SAFRAN

INTRODUCTION

Max KOESSICK

Jean-Grégoire IVANOFF

Jean-Christophe RAT

Safran Data Systems

Testing & Training in Motion

Introduction to Wireless Instrumentation

023

SAFRAN

Agenda

01

Helicopter FTI specifics

02

Safran DS and helicopters
HIRIS project

03

What’s next?

04

Remote devices: data & sync

05

Remote devices: power options

Chapter 1

Helicopter FTI specifics

Helicopter FTI specifics ► 2 main kinds of helicopters

- **Attack helicopters, eVTOL**
  - No cabin, no spare volumes, highly distributed FTI required (similar to fighter FTI)




- **Others**
  - Helicopters with cabin
  - Heavy or light, civil or military
  - Mostly centralized FTI inside a dedicated rack mounted in the cabin

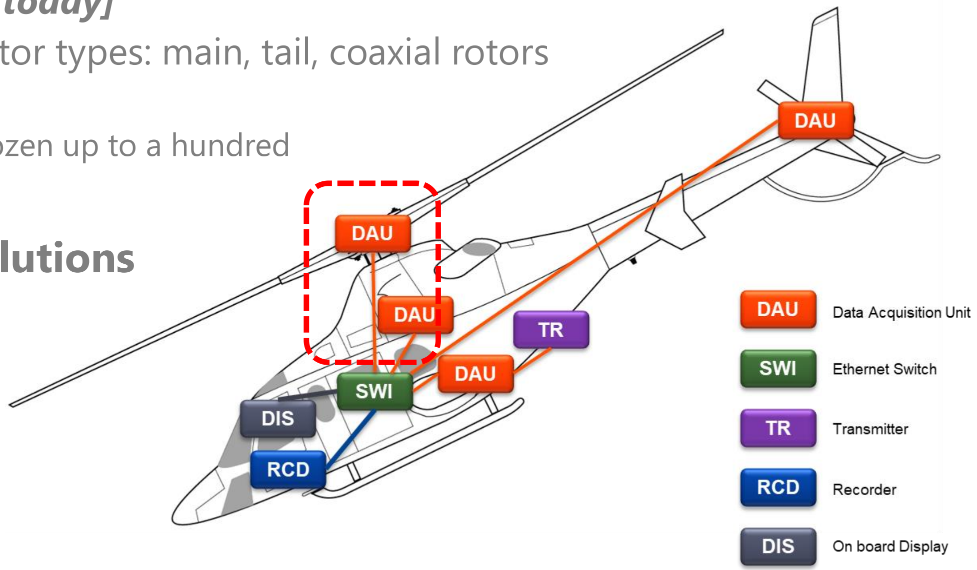




Helicopter FTI specifics ► Rotor related constraints

- **Rotor instrumentation = technical challenges**
  - Rotation speed: 450-500rpm typ. for main rotor, 2250-3000rpm typ. for tail rotor (5-6:1 ratio)
  - Related balance concerns
  - Data (& power) transmission ***[Our main topic today]***
  - For a vendor, need to address very different rotor types: main, tail, coaxial rotors
    - With different sizes
    - With different numbers of measurements, from a dozen up to a hundred

- **Data (& power) transmission : typical solutions**
  - Slip rings, with 2 sub-categories
  - Contactless, with 2 sub-categories

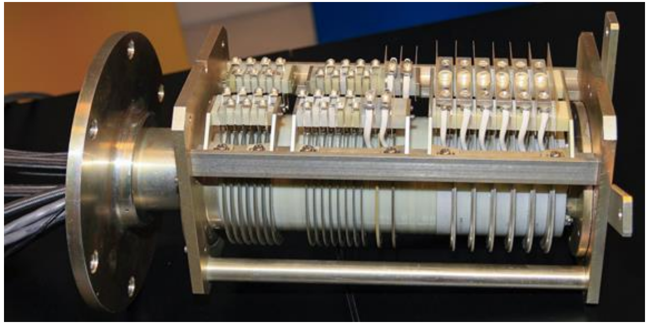


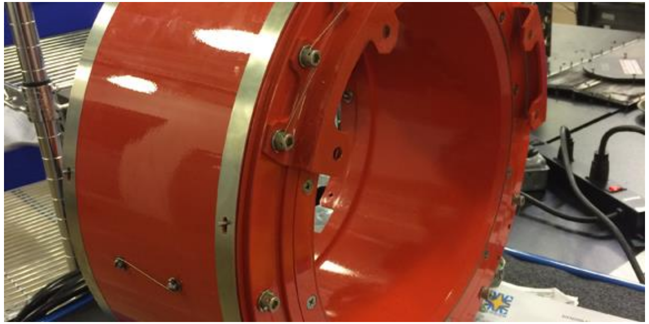
Helicopter FTI specifics ► Rotor related constraints

- **Data transmission with Slip Rings**
  - Option #1: **Analog** signals between sensors on the rotor and the DAU on the stator
    - PROs: simple, minimal instrumentation on the rotating part (sensors and wires)
    - CONs: limited number of channels (up to 4 lines per measure) and noisy
  - Option #2: **Digitization** by the DAU on the rotor the digital transmission over the slip ring (PCM, D+C, Ethernet, …)

- **Contactless Data transmission**
  - Option #1: **Inductive** = use induction to provide power, and modulate the inductive powering signal to transmit data
    - PROs: simple, single antenna system for power and data
    - CONs: noisy (radiated energy), limited bandwidth, no synchronization
  - Option #2: **Radio** transmission
    - PROs: different radio paths (centor of base of shaft, over or through the blades, …), bandwidth, (synchronization)
    - CONs: difficult to master the budget link (complex radio paths), accurate synchro requires bi-dir com, no power

Traditional Mechanical Sliprings





- **Prone to mechanical failure**
  - Relies on high MTBF bearing for continued operation
  - Bearing seizure = loss of a main control surface
- **High-wear brushes to transmit signal across rotating/stationary interface**
- **High maintenance**
  - Requires frequent cleaning and brush tension adjustment
- **Typical low density measurement count (<60)**
  - "Brush Bounce"

Case Study: Sikorsky SB>1 Defiant Wireless FTI

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- **In 2015, had to develop three independent wireless systems:**
  - Upper Rotor, Lower Rotor, Propulsor
- **Development challenges:**
  - **NO mechanical sliprings!**
  - Power – High Density LiPO
  - Antennas – Full 360 FOV Antennas. NO Doppler!!
  - Link Margin/Bandwidth – MPU3 Radios
  - GPS Synchronization – Rotating dedicated GPS antenna
  - Data Synchronization – Full IEEE1588 compliance for data stream re-assembly

Case Study: Sikorsky SB>1 Defiant Wireless FTI

- **Full Duplex Ethernet Transmission**
- **IEEE1588 PTP Synchronization**
- **Contactless – no moving parts**

This case study illustrates:

- What the helicopter industry **needs**
- That a **COTS solution** from a vendor could **spare a lot of complexity**

AIRBUS HELICOPTERS

HIRIS PROJECT

Chapter 2

Safran DS and helicopters

Safran DS & helicopters ► a long history

- **Data recording with MDR:**

  tried and tested on **over 20 helicopter programs**

Helicopters Programs	Country
MH-60R/S	USA
AH-1W/Z	USA
UH-1Y	USA
CV-22	USA
CH-47	USA
MH-60B/F/H	USA
UH-60	USA
MH-47	USA
OH-58	USA
HH-65	USA
CH-53	USA
AH-64	USA
NH-90	France, Germany
Tiger	France, Germany
EC135/145 (Troubleshooting)	Germany
SH-09	Switzerland
AW149, AW169, CH47	UK, Italy
LAH, LUH	India

SAFRAN

Safran DS & helicopters ▸ a long history

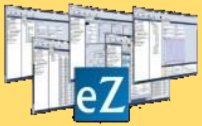
Testing & Training in Motion

- Full FTI systems: Kopter SH-09 success story

Risk-free + short schedule FTI system

- From FTI design to flight in 10 months
- Scalable FTI system adopting Ch10 format, network telemetry…
- 100% in-house products

3x XMA	1x Advantys
1x MDR	1x RX1 + GMDR
1x Tx	1x Comtrack



eZ Software suite

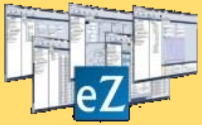
- Configuration
- Live Monitoring & Control
- Quicklook
- Decomm & Display

SAFRAN

Safran DS & helicopters ▸ a long history

- Full FTI systems: MHI SH60K success story

7x XMA (2x XMA on main rotor)
1x MDR 1x Switch



eZ Software suite

- Configuration
- Live Monitoring & Control
- Quicklook

Hybrid architecture mixing:
- RS-link
- ETH-link
- IENA
- PCM Ch4

500g qualification successfully passed for XMA tail rotor

Safran DS & helicopters ▸ HIRIS project presentation

Testing & Training in Motion

- **FRC / RACER (Rapid and Cost-Effective Rotorcraft)**
  - New economic and environmentally friendly helicopter able to fly up to 220 nots,
  - Would expand range and speed for critical rescue missions,
  - Designed by Airbus Helicopters & partners,
  - Subsidized by European CleanSky2 program.

Clean Sky 2
JOINT UNDERTAKING

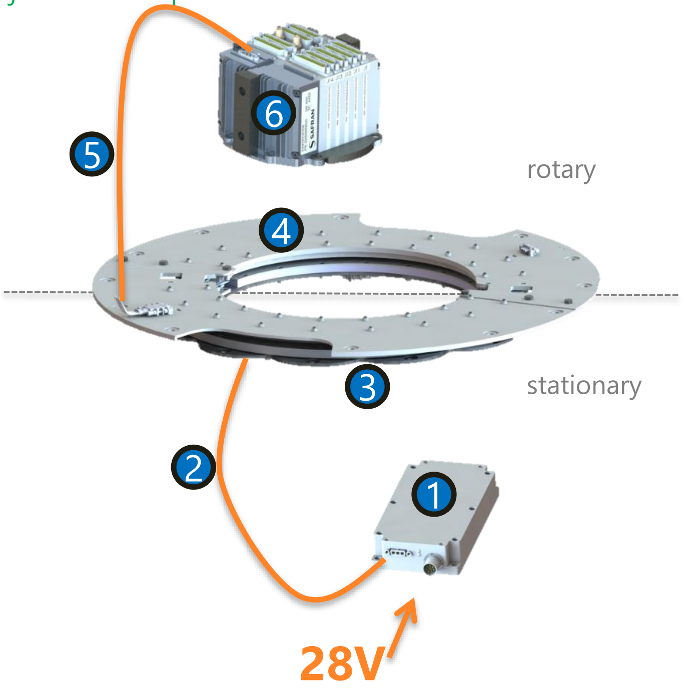
- **Helicopter Innovative Rotating Instrumentation System (Goals)**
  - Instrumentation of Main and Lateral Rotors with up to **128** channels,
  - **Wireless Inductive** powering system up:
    - Drastically limit the undesired radiations of magnetic fields,
    - Use a sophisticated, low cost and safe power transfer technology,
  - Wireless lossless datalink up to **50Mbps** useful data (for all 3 rotors),
  - Wireless system synchronization down to **50ns**,
  - Wireless system configuration based on **eZ software suite**,
  - Mechanical design and substantiation for installation on rotor head

SAFRAN

Safran DS & helicopters ▸ HIRIS wireless inductive power

Take aways:
- Very robust power transmission,
- Live health monitoring available (eZ and/or TM),
- Up to 80% yield,
- Mechanicaly justified and qualified

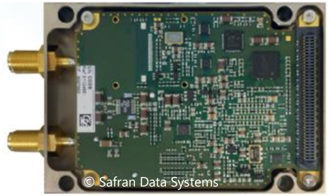
- **Stationary part**
  - Inductive Power Converter and Transmitter IPCT 1
  - Inductive cable 2
  - Inductive Coil for Transmission ICT 3
- **Rotary Part**
  - Inductive Coil for Reception ICR 4
  - Inductive cable 5
  - Inductive Power Receiver Module 6
- **Health Monitoring for both IPCT and IPR,**
  - IPCT/IPR: Internal temperatures,
  - IPCT/IPR: Inductive frequencies,
  - IPCT: 28V power consumption,
  - IPR: secondary power lines consumption,
  - IPCT Status transmitted through the inductive link to the rotating DAU



Safran DS & helicopters ▸ HIRIS wireless Data & Sync

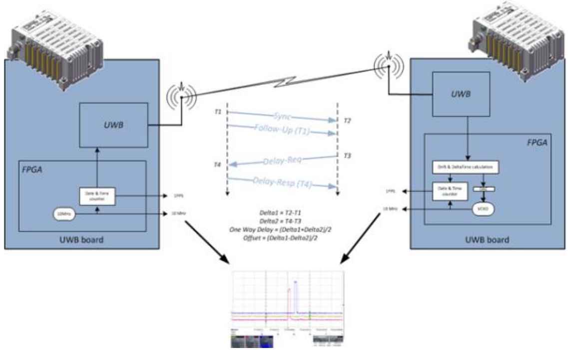
- **XMA-WLS: wireless dual technology**
  - UWB for synchronization,
  - WiFi for large data transfer (step1 up to 20Mbps)
- **WiFi**
  - WPA2 Encryption
- **UWB**
  - Mastering very low OSI levels (1, 2, 3)
  - PTP-like synchronization implementation
  - Natively robust to multi-path (RF pulsed technology)
- **Diplexer**
  - Combines UWB and Wifi signals on one unique antenna,
  - Low attenuation filter to separate UWB from Wi-Fi frequencies

XMA-WLS



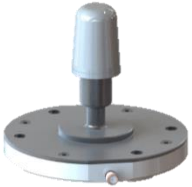
IR-UWB

802.15.4a



Data rate	Synchronization	Standard	Range in FTI environment
Up to 30Mbps (WiFi) Up to 6Mbps (IR-UWB)	<100ns	802.11.n WiFi 802.15.4a IR-UWB	Rotor to helicopter tail

Diplexer

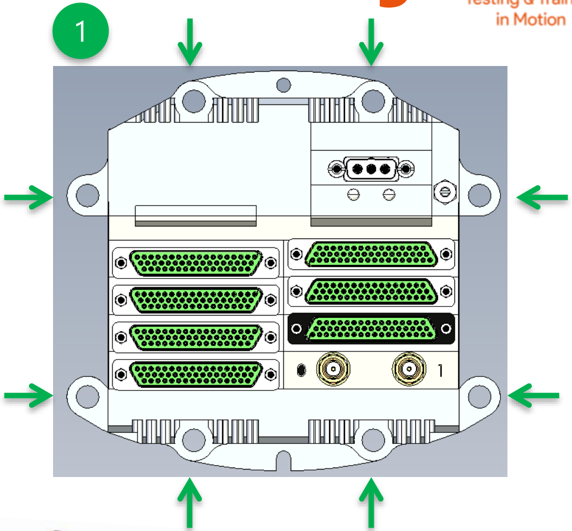


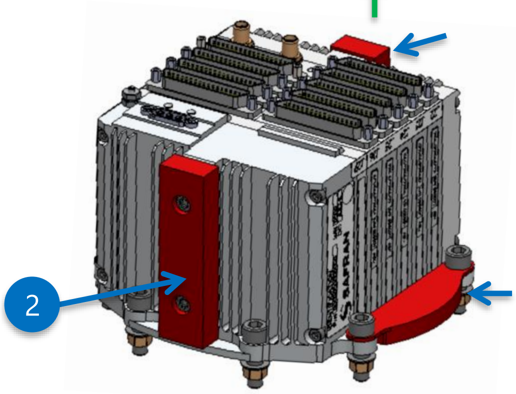
Safran DS & helicopters ▸ HIRIS specific mechanical design

Testing & Training in Motion

Not related with wireless topic, but by the way:

- **All mechanical design & substitution has been done:**
  - In accordance with AH ROTOR'S specialist requirements,
  - In compliance with DOA safety rules leading by CS29,
- **Reinforced mounting holes (8xM6 screws),**
- **Locations for Balancing weights,** 1
- **Cubic form factor with top oriented connectors** 2





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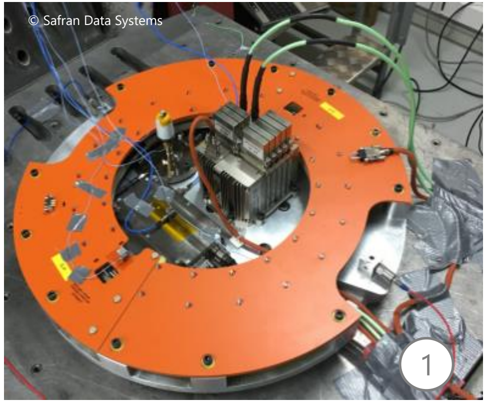
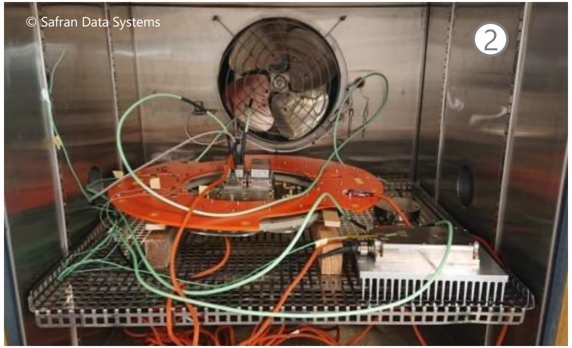
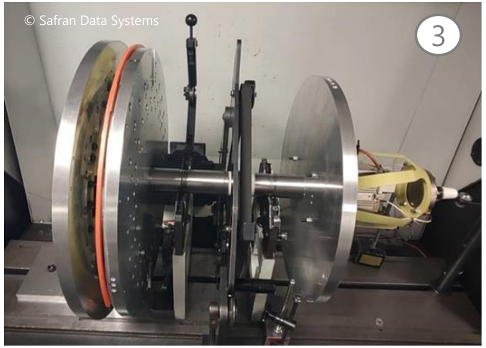
Safran DS & helicopters ▸ HIRIS achievements

- **Qualification Test results**
  - Pass Criteria:
    - Induction power yield variation < **5%**,
    - Synchronization <**100ns**,
    - No data loss for 64 parameters at **8192sps**,
  - ① Vibrations / Shocks passed
  - ② Climatic operational test -40 +85°C passed
  - ③ Rotation test passed up to 2350 rpm

Take Away: sensitivity to antenna position increases with speed rotation over 600rpm!

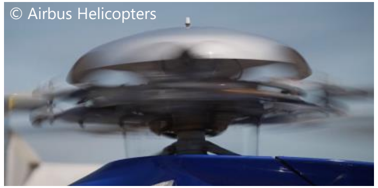






Safran DS & helicopters ▸ HIRIS achievements

- **First flights at Airbus Helicopters**
  - Lab testing + Ground and Flight test on H175
  - 60+ flight hours with very promising results!
    - Very **stable** inductive **power** link,
    - Very **robust WiFi** link,
    - UWB is functional but with unexpected low level in reception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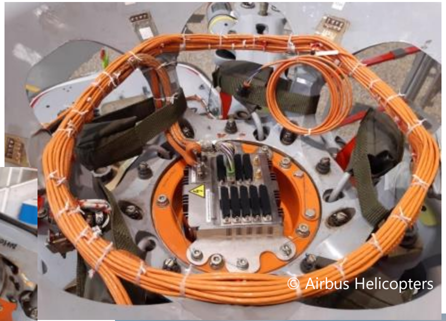
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Safran DS & helicopters ▸ HIRIS achievements

- HIRIS System's being installed on the RACER

- First flight expected by the end of 2023!

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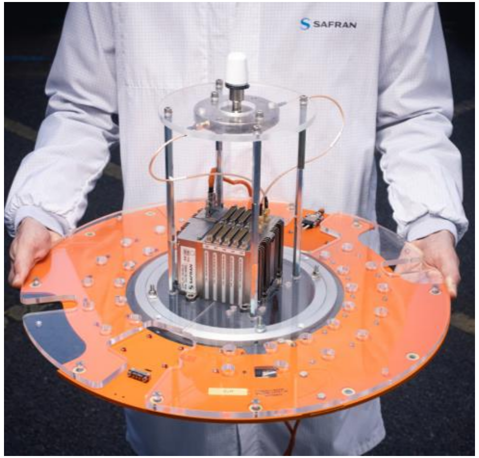

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Chapter 3

What's next at Safran DS?

Testing & Training in Motion

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What's next at Safran DS?

Exciting on-going innovations for the helicopter / rotary-wing market include:

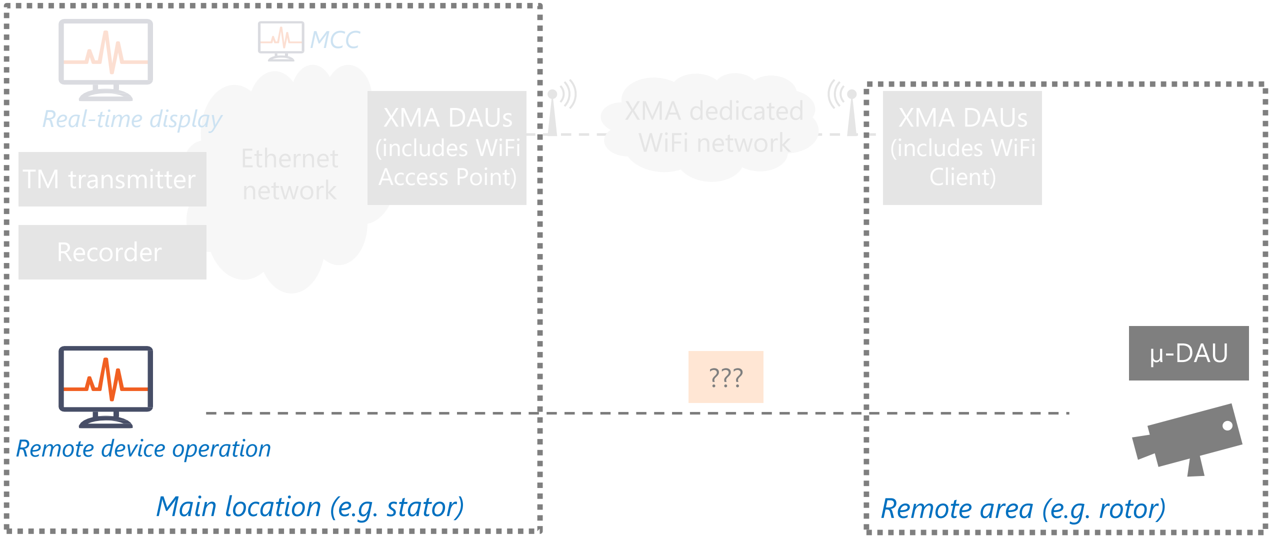
- **HIRIS offspring: from Prototype to Product**
  - Industrialization of XMA-Rotor chassis (specific form factor, inductive power)
  - Variants created regarding power input (non-inductive 28V) … or output (see next chapter!)
  - Finalization of WLS module functionalities
- **Misc solutions to integrate remote devices in a system** (see next chapter!)
  - Already running: capture Ethernet traffic in remote area using IPX module
  - Mid term: extend Ethernet network to remote area using Tunneling capability
  - Long term: release µ-DAU dedicated to remote areas
- **Adding Fiber Sensing** (see dedicated training & hands-on!)
  - Partnership with 3rd party Fiber Optic Interrogator
  - Current state: XMA able to interface with Fiber Optic Interrogator
  - Next step is to roll the Fiber Optic Interrogator into an XMA module

Chapter 4

Remote devices: data & sync

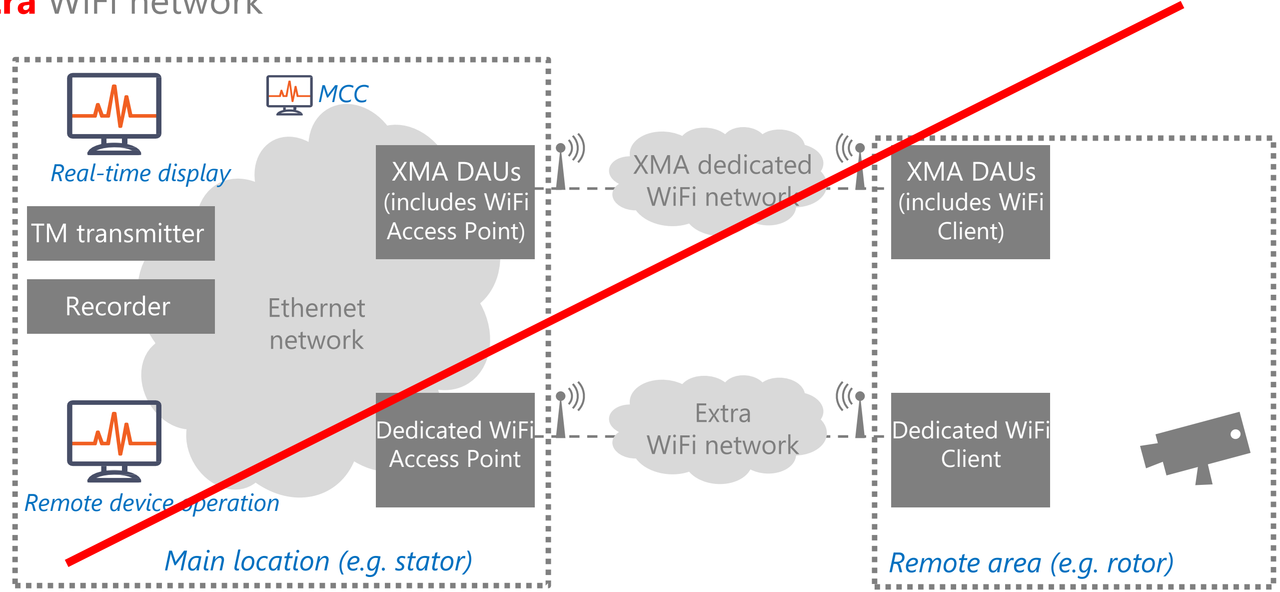
Remote devices

- **How to take advantage of a remote DAU system to operate other remote devices?**
  - Even smaller, more ruggedized micro-DAUs
  - 3rd party devices delivering DAU or non-DAU function (e.g. IP camera)
  - Possibly not equipped with native wireless interface



Remote devices: data & sync

- **Overkill solution**
  - Use an **extra** pair of WiFi access point & client devices (in addition to the DAU system)
  - Install **extra** antennas
  - Set up an **extra** WiFi network



Remote devices: data & sync

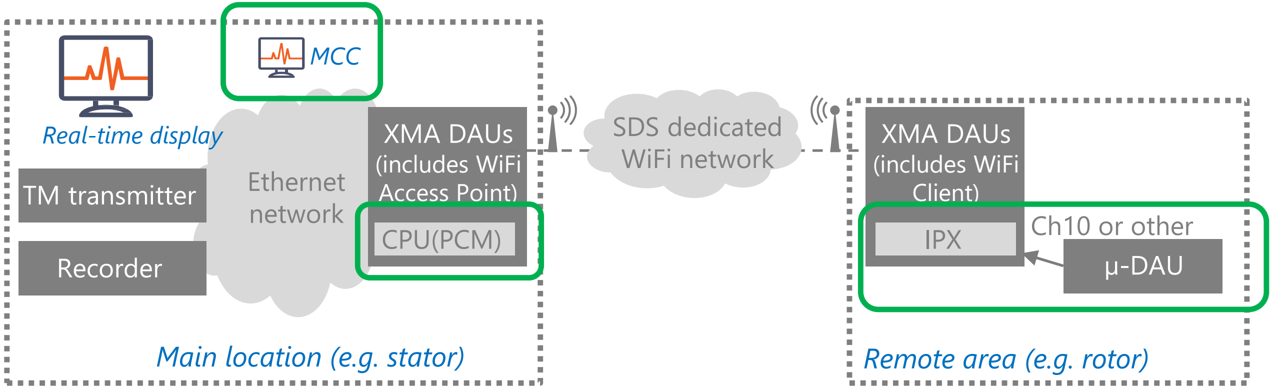
- **Safran DS off-the-shelf solution (DAU oriented function)**
  - Already possible to set up a **PCM data merger** solution
  - A 3rd party micro DAU outputs a PCM or Ch10 or other stream containing samples
  - An XMA-IPX extracts the samples and propagates them to root PCM generator using SDS protocol
  - An XMA-CPU inserts the samples in a PCM minor frames using a “CVT” mode (Ch10 packetization possible)

Benefits:

Available, and well suited for customers used to **PCM decom software**.

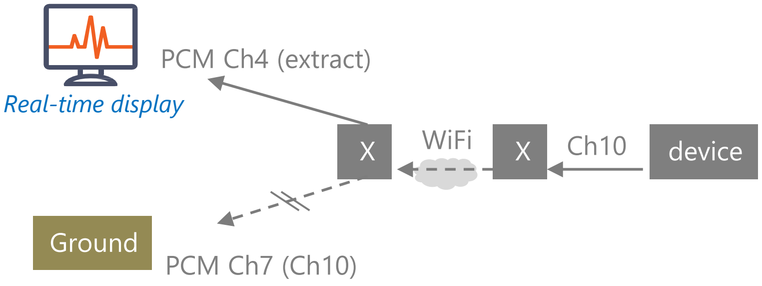
Limitations:

Does not address **device synchronization** and alters **synchronous data**

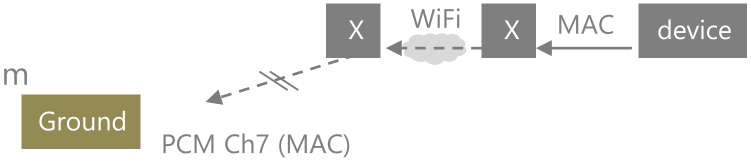


Remote devices: data & sync

- **Safran DS <u>off-the-shelf</u> solution (any type of function)**
  - More options allowed with IPX/CPU/(ETH) solution
  - Either capture full and/or extractions of **Ch10** traffic:
    - CPU merges Ch10 extractions into standard Ch4 stream
    - CPU streams Ch10 data as part of a Ch7 stream



  - Or capture **raw MAC** frames (or **IP** packets):
    - CPU streams these MAC frames (or IP packets) as part of a Ch7 stream



Remote devices: data & sync

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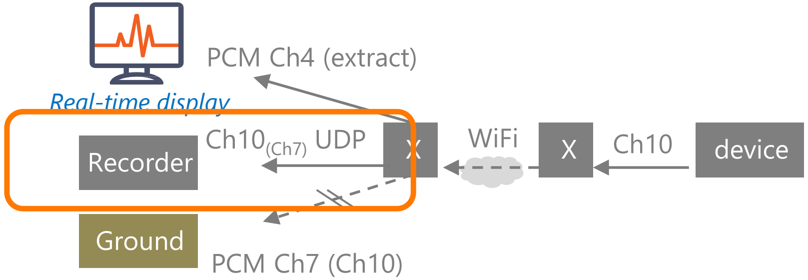
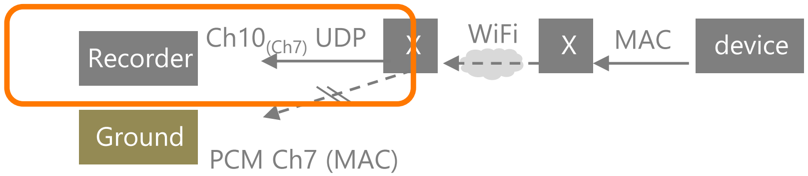
  - Either capture full and/or extractions of **Ch10** traffic:
    - CPU merges Ch10 extractions into standard Ch4 stream
    - CPU streams Ch10 data as part of a Ch7 stream
    - Less efficient: Ch7 encapsulation to UDP Ch10 => see next!
  - Or capture **raw MAC** frames:
    - CPU streams these MAC frames as part of a Ch7 stream
    - (Less efficient: Ch7 encapsulation to UDP Ch10 => see next!





Remote devices: data & sync

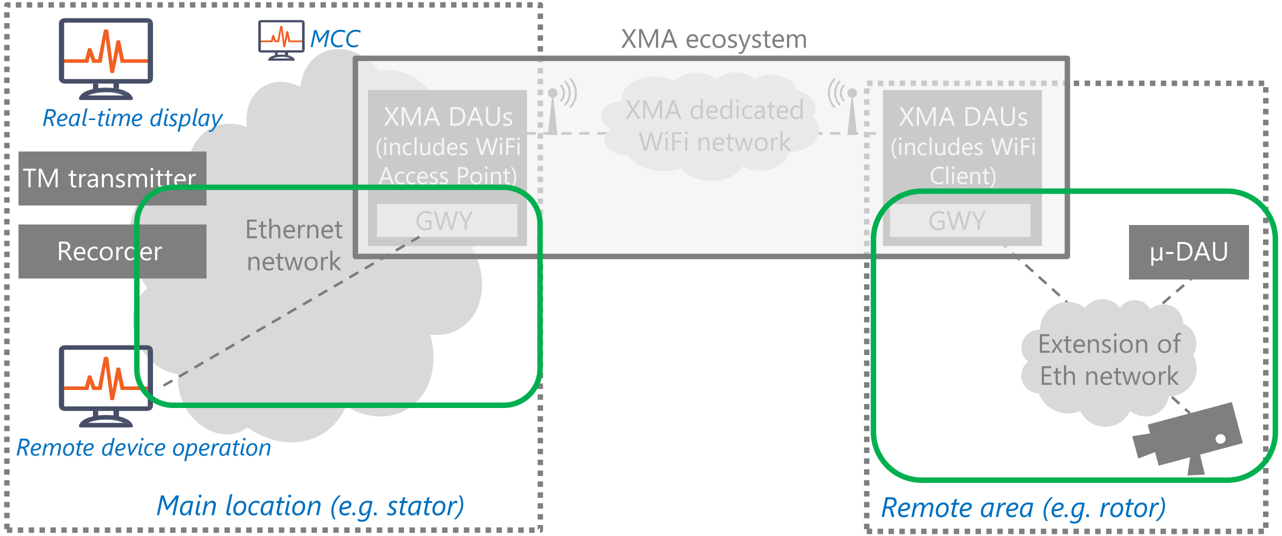
- **Safran DS <u>mid-term</u> solution (any type of function)**
  - Currently working on a **tunneling** solution, based on new XMA-GWY module
  - Turns the XMA ecosystem into a "black box" that third-party traffic may travel through **transparently**
  - Adds an additional PTP master **(Boundary clock)** capability on remote side

Benefits:

Applicable to any device, **respects** any **native** service **characteristics*** offered by the remote device.

(as if it were connected to the main Ethernet network).

Also supports **device synchronization**.



* Exceptions exist, see PTP

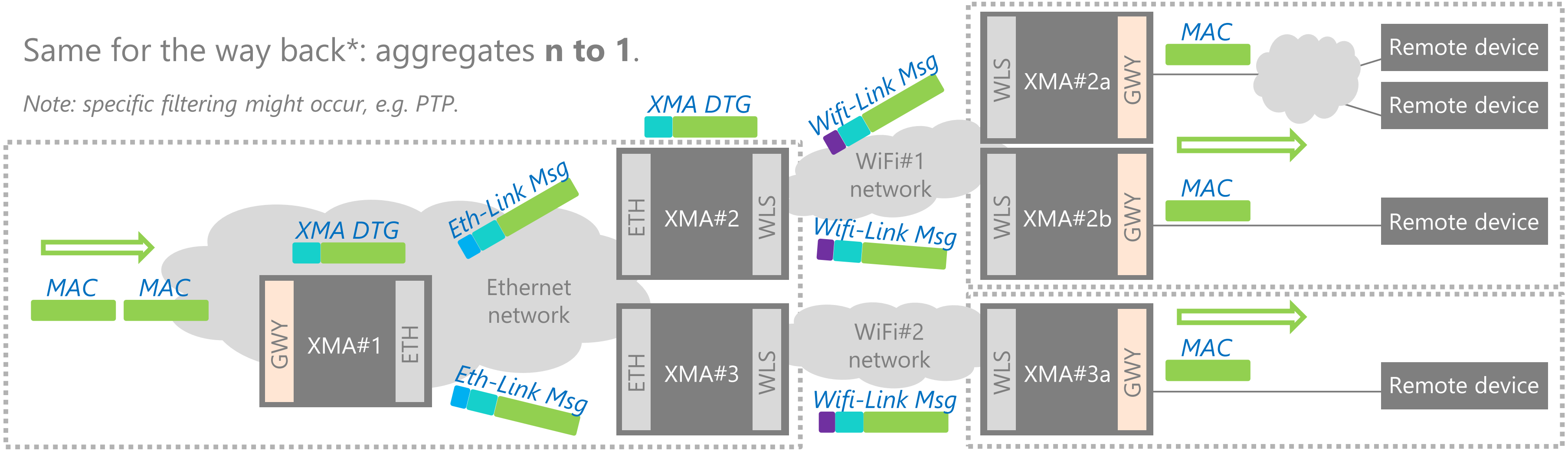
Remote devices: data & sync

How an XMA ecosystem actually performs Tunneling:

- Collects MAC frames received by the GWY module located on the main network
- Encapsulates these MAC frames in a proprietary format
- Propagates to **all*** GWY modules located on remote area(s), using SDS Eth-Link and Wifi-Link protocols
- Replays MAC frames unchanged on remote links or networks

Same for the way back*: aggregates **n to 1**.

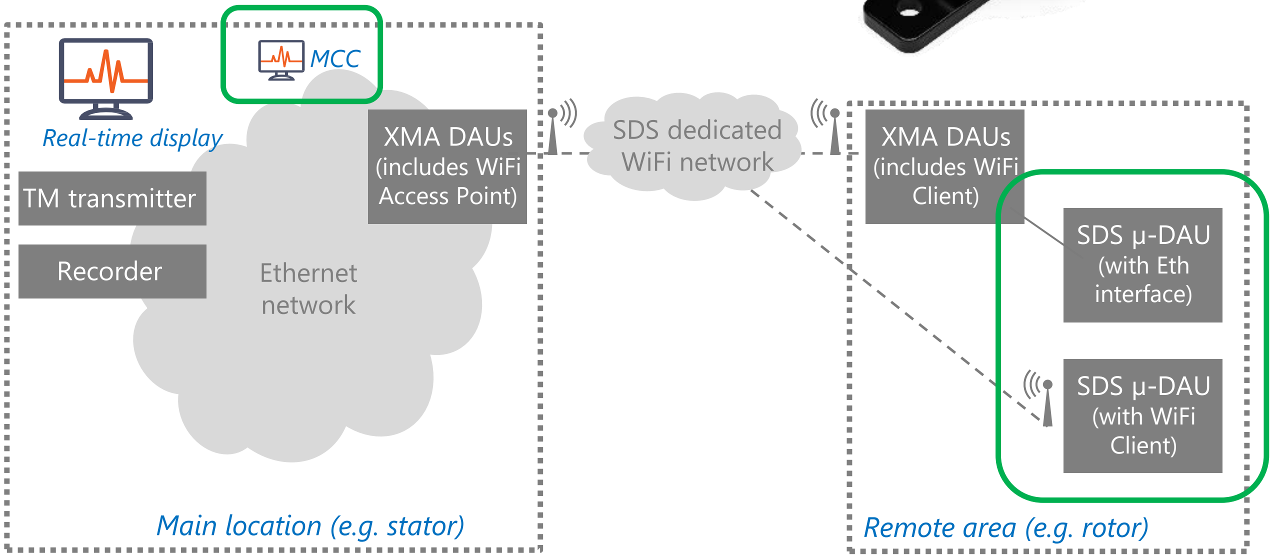
Note: specific filtering might occur, e.g. PTP.



Remote devices: data & sync

- **Safran DS <u>long-term</u> solution (DAU oriented function)**
  - Currently working on a **micro-DAU** product named **µMA**
  - Small & ruggedized
  - Running on batteries
  - Will come in Ethernet & WiFi versions
  - Will leverage SDS proprietary protocol to fully integrate into SDS ecosystem (~XMA/MDR combo system)

Benefits:
Will natively support **device synchronization** & preserve **synchronous data**



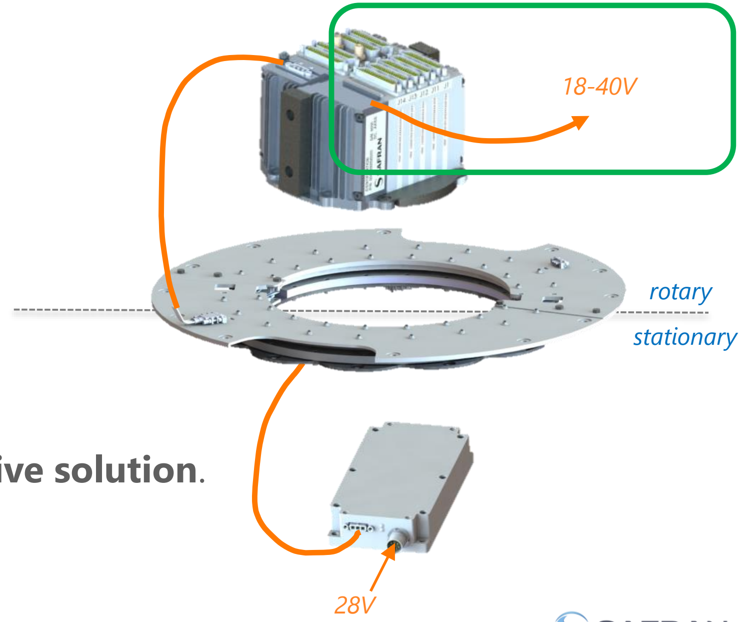
Chapter 5

Remote devices: power

Remote devices: power

- **Last step to a truly wireless device operation: power!**

- **Safran DS currently considers extending HIRIS ROTOR functionalities**
  - Either as explicit **18-40V** power sources
  - Or as a standard solution like **PoE** (Power over Ethernet)

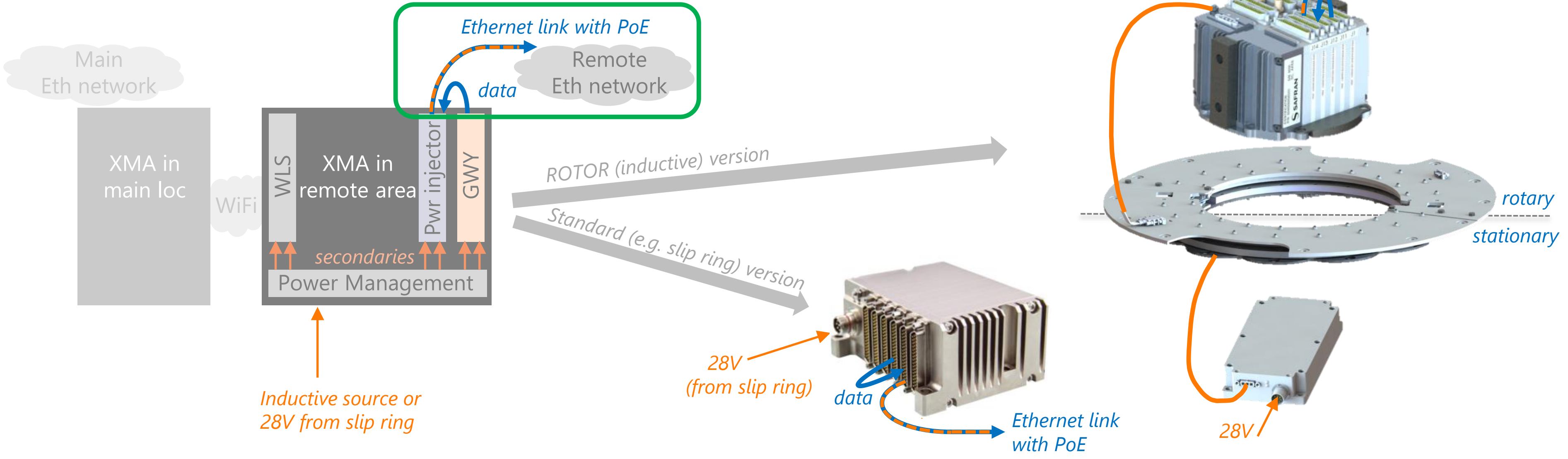


▶ 18-40V option

- Safran DS considers deriving a regulated power source, possibly configurable, on the Rotor side of HIRIS **inductive solution**.
- This would be available on a dedicated connector.

Remote devices: power

- **PoE option (not limited to ROTOR form factor)**
  - Would be combined with XMA-GWY based **tunneling** solution
  - Would use a dedicated module to inject power derived from DAU power supplies
  - Not limited to ROTOR form factor (if XMA gets its power from another source)



TRAINING

Ghislain GUERRERO

Innovation and Business Dev Director

Safran Data Systems

TiM

Testing & Training in Motion

Fiber Optic Sensing

023

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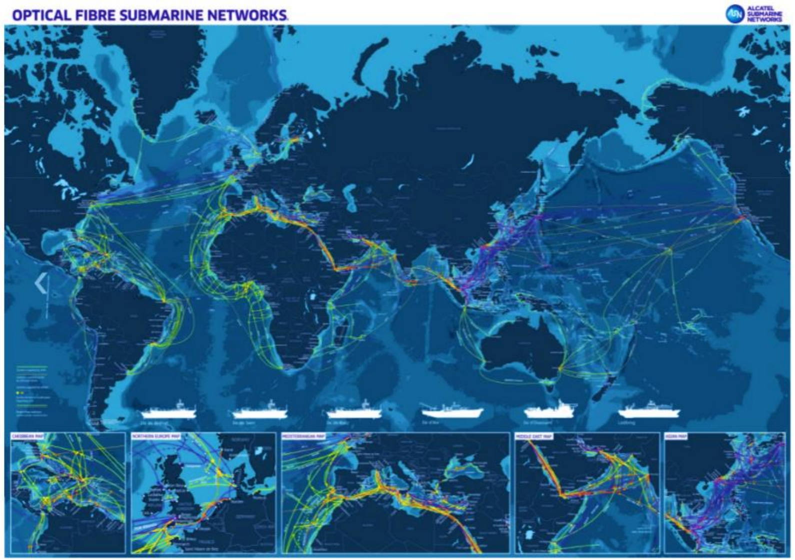
Agenda

Introduction

General presentation of optical fiber applications

- **Well known in the field of telecommunications**
  - Made possible higher transmission data rates over longer distances

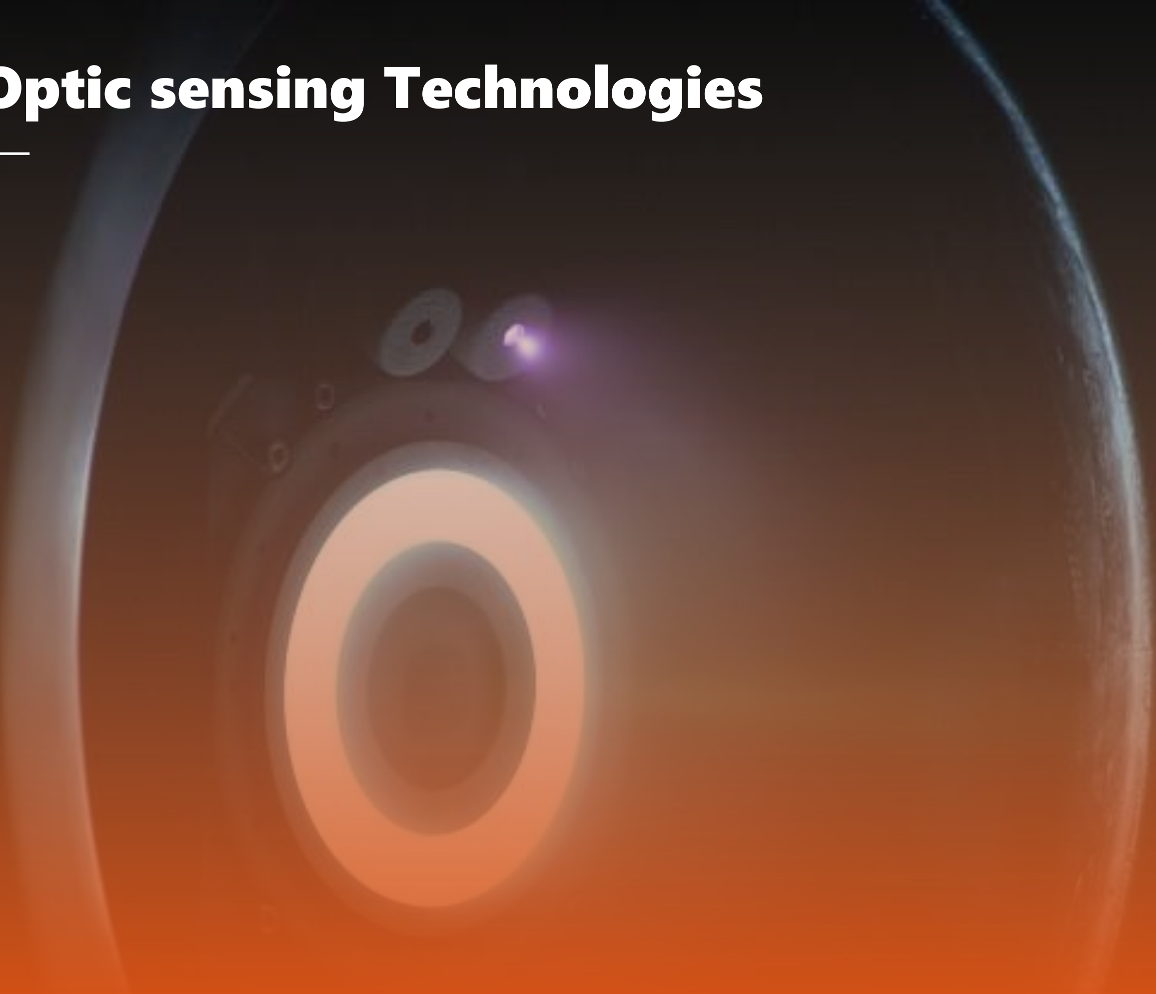


Source : ASN (Alcatel Submarine Networks)

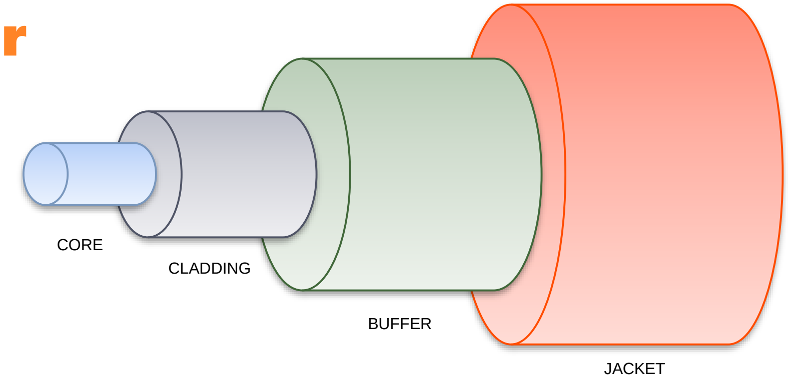
- **In parallel, fiber optic found rapidly growing use in the field of sensing for various applications …**
  - Energy: Oil and Gas, dams, wind energy, nuclear plants…
  - Civil engineering: Bridges, structures and tunnels monitoring…
  - Transportation: Railway…
  - Many others such as smart factories, biomedical…

- **… Thanks to fiber optic intrinsic properties:**
  - Reduced weight and size.
  - Immune to harsh environments: high temperature, electromagnetic interference and/or irradiated environments.
  - High density of sensing points along the fiber optic and good metrological performances (Precision, sampling rate, measuring range…).

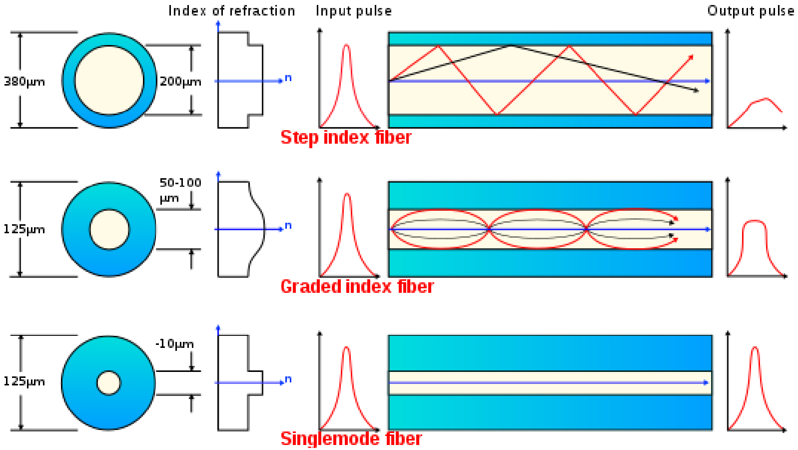
Fiber Optic sensing Technologies



General presentation of optical fiber



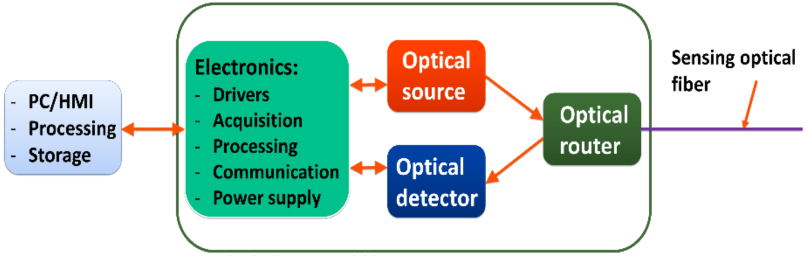
- **Made by drawing glass (silica)**
  - A **core** surrounded by a **cladding**
- **Cylindrical waveguide for light**
  - Cladding (Index of refraction) < Core (Index of refraction)
  - Leads to **total internal refection**
- **2 main types**
  - **Multi-mode fibers (MMF)**
    - Core: 50-200µm typ. / Cladding: 125-400µm typ.
    - Light ray dispersion due to multipath propagation
  - **Single Mode Fibers (SMF)**
    - Core: 8-10µm typ. / Cladding: 125µm typ.
    - Single direct axial light ray propagation
    - Single mode for a given wavelength (typ. infrared)
- **Light source**
  - LED or Laser



Source: wikipedia

Fiber optic sensing technologies

- Different fiber optic sensing (FOS) solutions available in the market but globally based the same architecture



Block diagram of fiber optic sensor interrogators

- FOS can be divided into 3 main categories

Distributed sensing systems	Quasi-distributed sensing systems	Point (Punctual) sensing systems
- OTDR / OFDR (Based on Rayleigh, Raman, Brillouin phenomenon) - High number of sensing points along the fiber (up to 10s of thousands) - Slow acquisition rate (up to ~ 100s of Hz) - Measures temperature, strain…	- Fiber Bragg Gratings (Based on WDM) - Moderate number of sensing points (approx. 10 to ~100) - Acquisition rates up to 10s of kHz - Measures temperature, strain, displacement…	- Single sensing point often based on interferometric cavity (Fabry-Perot) - Acquisition rates exceed 100 kHz - Measures pressure, temperature, strain…

Fiber Bragg Grating – FBG 1/5

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- **Leading edge FS-Laser Processing**
- **From Safran's partner: FiSens GmbH**
- **4th generation proprietary laser processing: accurate, robust & scalable**
  - Ultra short laser pulses create high precision nanoscopic strucutures in commercial available telecom optical fibers
  - Direct focus into the core through the cladding
  - Complete freedom in positionning fiber Bragg grating sensors along the fiber

FiSens

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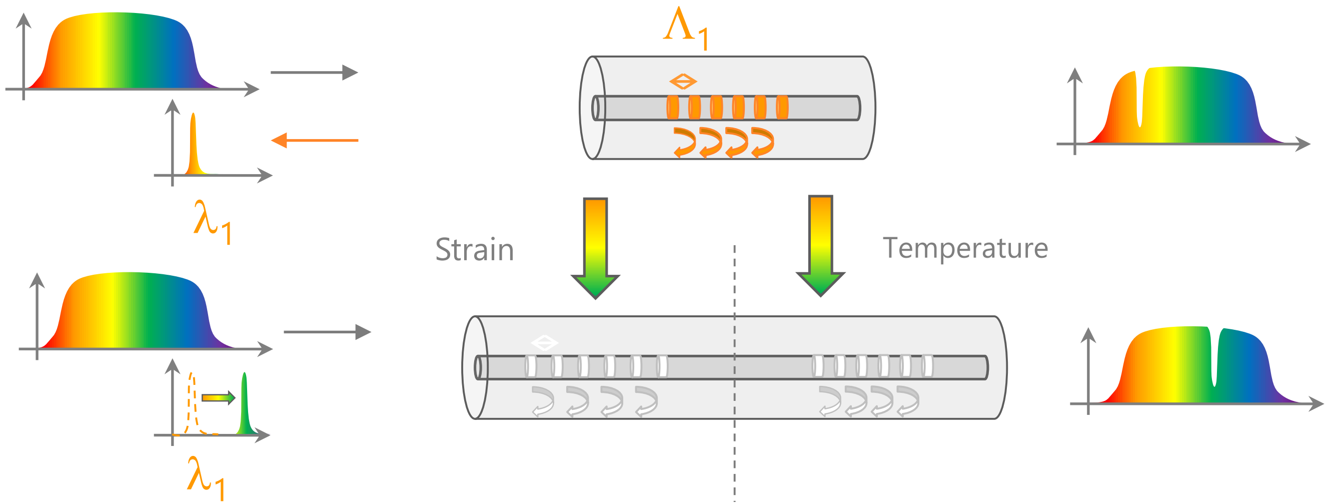
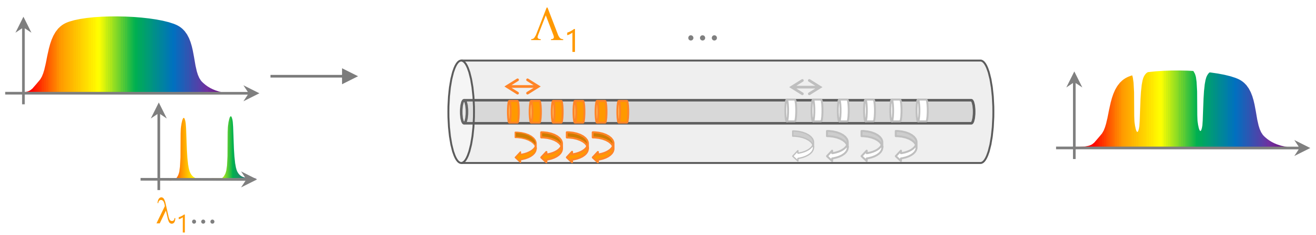
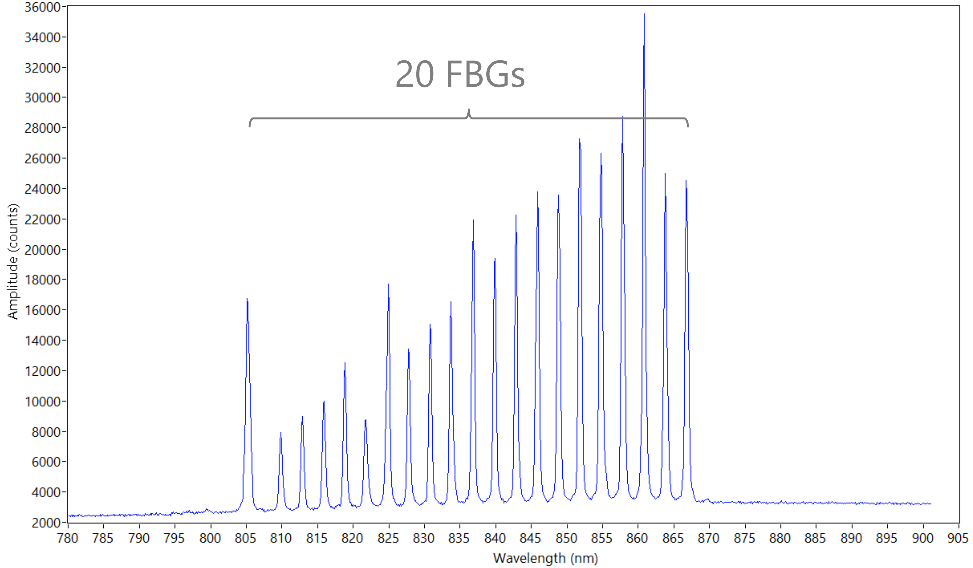
Fiber Bragg Grating – FBG 2/5



- **Principle :**
  - Fiber Bragg Grating = modulation of core refractive index (where Λ is path)
  - A part of incident light is reflected by FBG, it is the Bragg wavelength (λ_B), while the other part is transmitted.
  - λ_B shifts when a strain or temperature variation is applied to FBG.
  - This technique allows localized measurement of temperature and/or deformation along the optical fiber

Fiber Bragg Grating – FBG 3/5





- **Multiple FBG sensors spectrally multipexed along a single optical fiber.**
- **Each FBG acts as a sensing point**

Fiber Bragg Grating – FBG 4/5

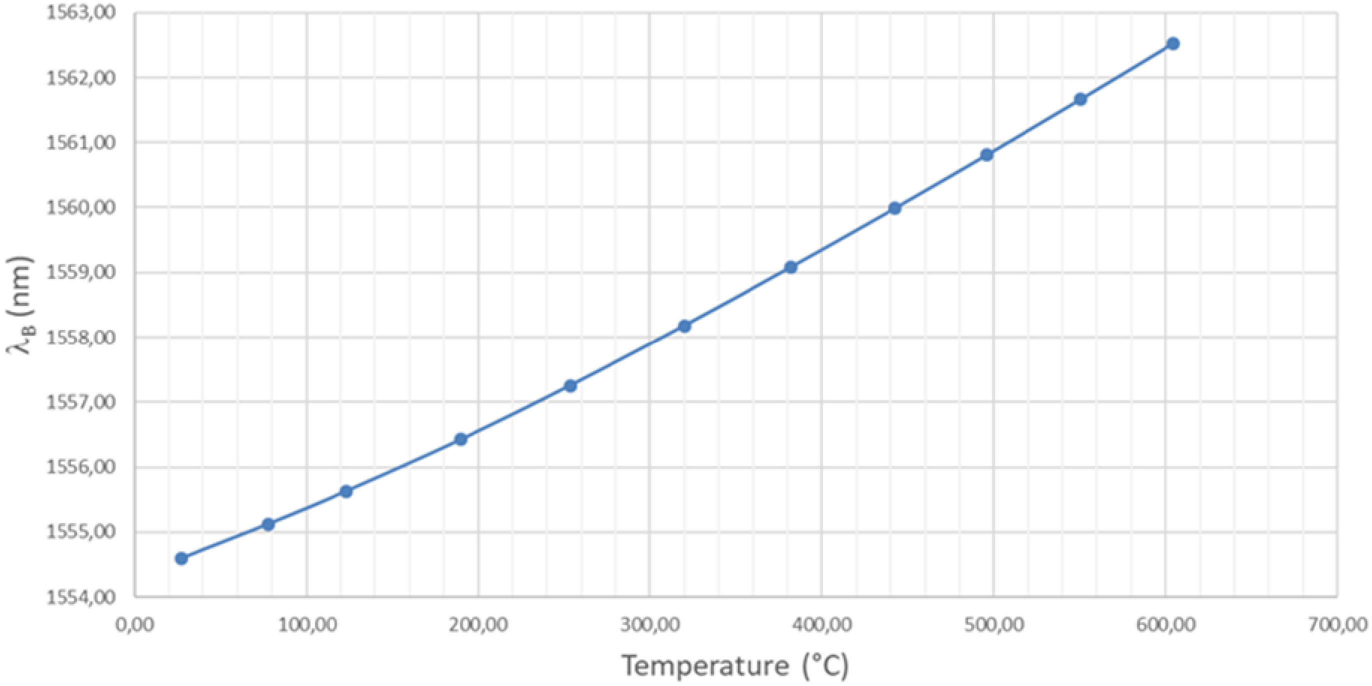
- **Simplified Fiber Bragg Grating formula: $\lambda_B = 2\ n_{eff}\ L$**
  - n_{eff} : effective index of the guided mode of the fiber (usually approximated by the refraction index of the core)
  - L : step of the grating

- **Simplified formula of the wavelength spectral shift : $\Delta\lambda_B = k_e\ e + k_T\ \Delta T$**
  - $e = \Delta L/L$
  - For 1550nm
    - k_e~ 1,2 pm/µε
    - k_T~ 10 pm/°K (or [+20; +100°C] but increases with higher temperature → e.g. ~16 pm/°K for [+400°C; +800°C]
  - For 850nm
    - k_e~ 0,67 pm/µε
    - k_T~ 7,5 pm/°K

- **Note: FBG is less sensitive at 850nm than 1550nm**

Fiber Bragg Grating – FBG 5/5

- Exemple of λ_B = f(Temperature)



FBG in the field of aeronautics

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- **Need for various physical parameters monitoring**
  - Temperature sensing at different locations : engine, nacelle, landing gear, cabin and seat …
  - Strain measurement : Wings, landing gears, fuselage …
  - Static and dynamic pressure measurement
  - Health assessment of structural elements : composite materials, metallic parts, tanks …

- **The aeronautic field implies to take into account specific challenges related to harsh environments**

Interrogator	Reliability	Metrology	Fiber Integration	Costs
- Airborne compatibility (weight, volume) - Environmental stress (temperature, vibration, sealing…)	Due to the long lifetime of the devices, strong environmental constraints (thermal cycling…) are required	- Acquisition frequency - Number of sensors/channels - Accuracy, noise and stability …	- Routing fibers along different paths and in harsh environments - MRO	Cost effectiveness to allow deployment on a larger scale

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FBG in the field of aeronautics

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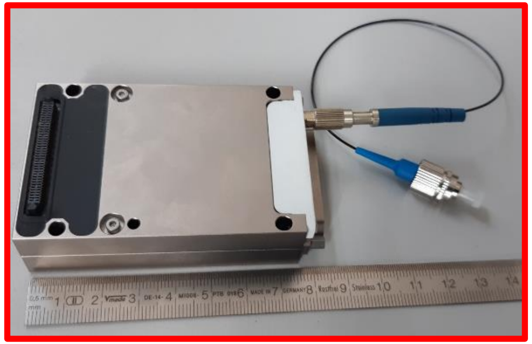
On going projects aim to adress these aspects



Optical XMA module dedicated to FBG measurement

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Fiber Integrated Spectrometer

Design of a state-of-the-art Spectrometer

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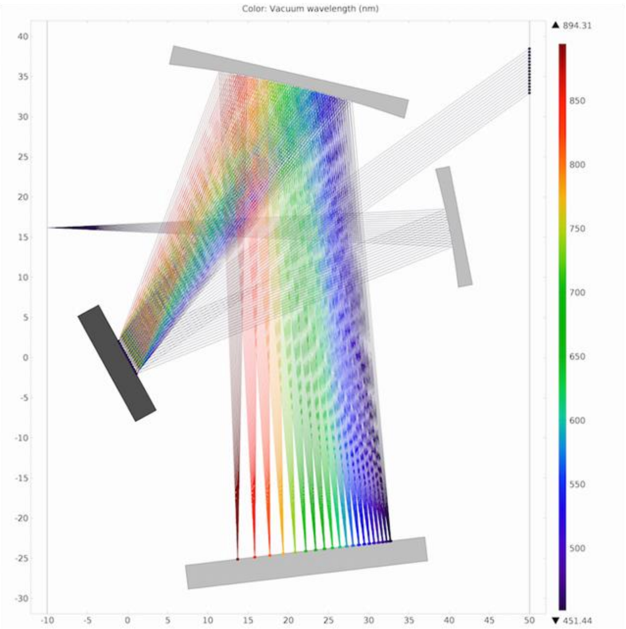
- 5 different components need to be precisely aligned



  - Slit
  - Collimating mirror or lens
  - Diffractive grating
  - Imaging optics
  - Detector

- **All components to be produced with high precision and narrow tolerances**

- **To be aligned to each other in a precise and cumbersome manual procedure**

- **High optical resolution requires long optical path**

- **The more components and the longer the optical path, the less thermal stability and vibration/shock resilience**

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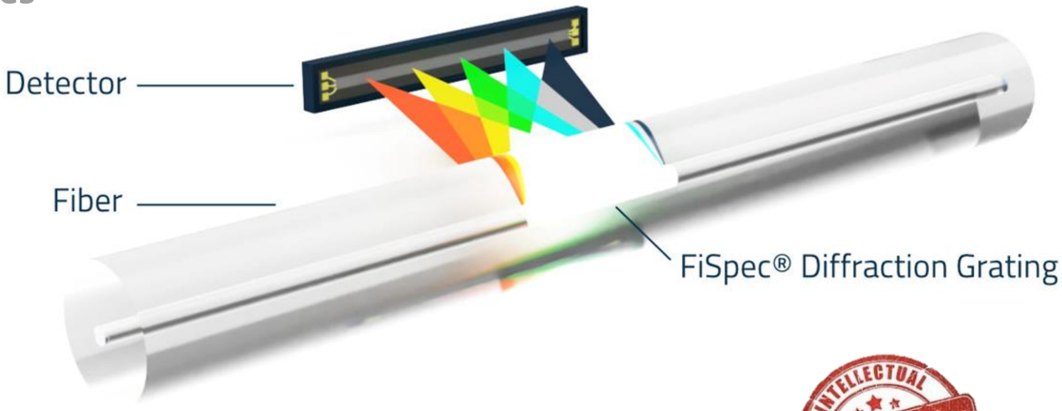
Unique Fiber-Integrated Spectrometer

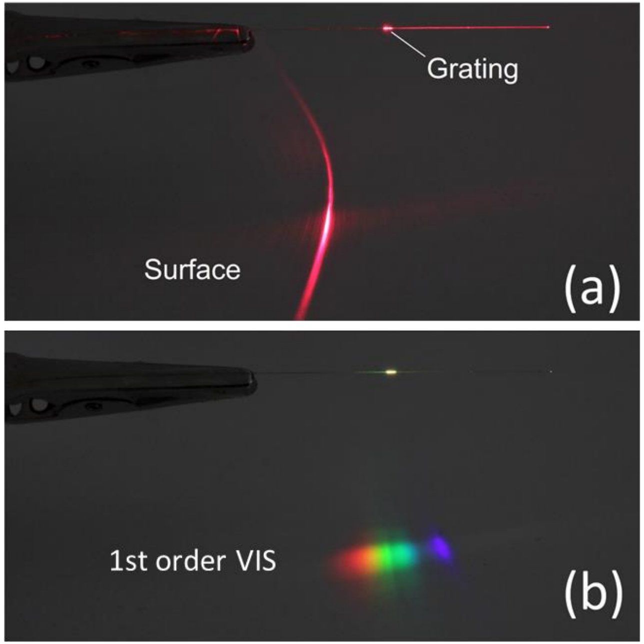
- All optical components of a spectrometer within a single optical fiber
- Unique in-core grating for out coupling and direct focusing onto image sensor with ultra-high diffraction efficiencies and light intensities
- Spectral resolutions from 50pm to 2nm directly encoded
- Customizable to almost any desired wavelength (200-2000nm)
- Quasi-monolithic design for highest shock-resistance and thermal stability
- Unprecedented cost-effectiveness and automatic production scalability

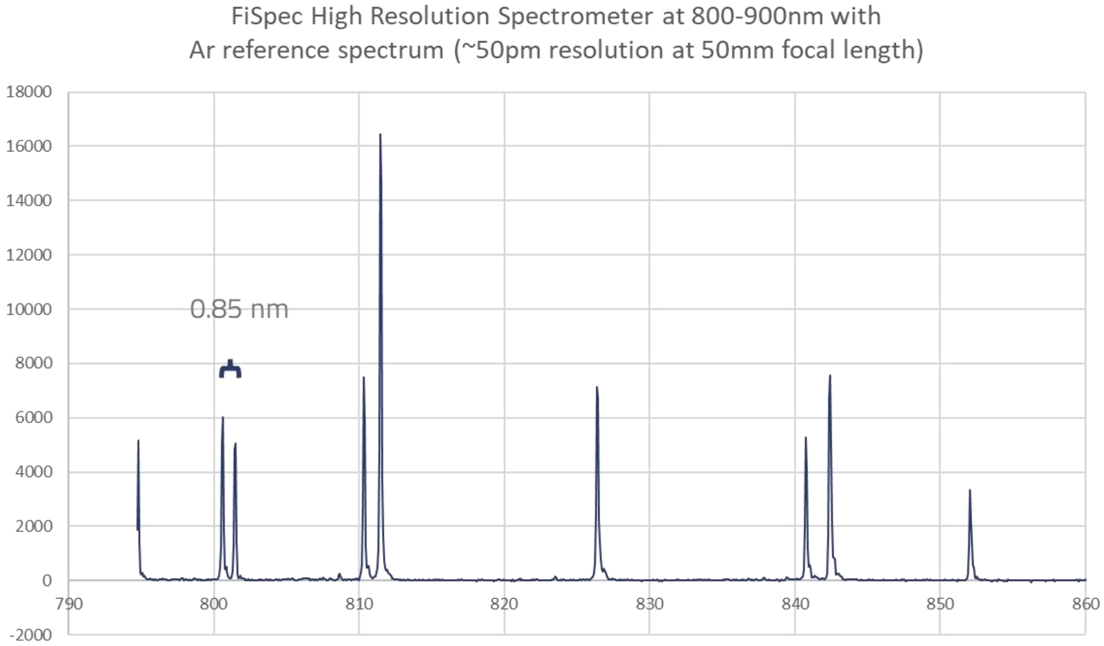


US 10962415 B2 EP 3586177 B1

Ultra-high resolution imaging on a tiny fooprint

- All optical components of a spectrometer within a single optical fiber



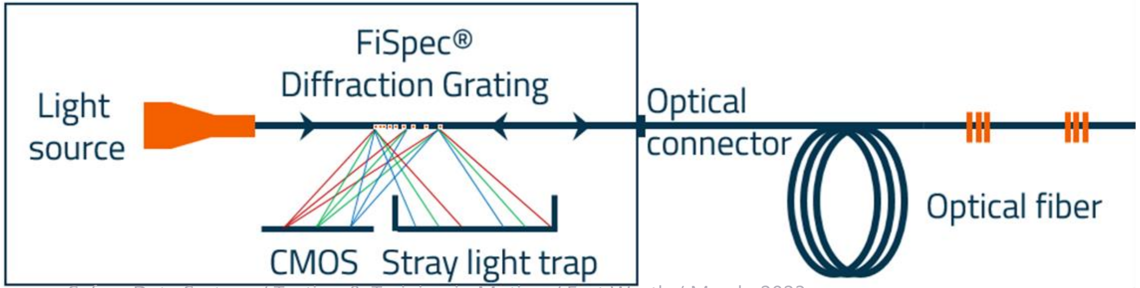


Ultra-Compact FBG Interrogator for airborn applications

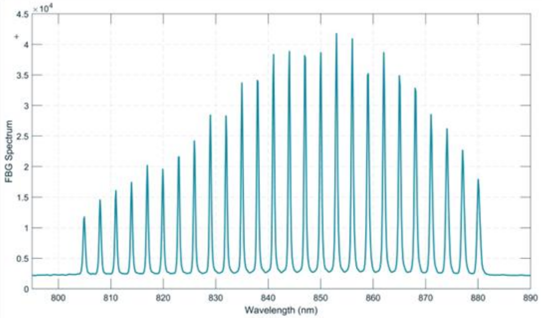
- **Fully-integrated system within XMA stack**
- **Bi-directional approach**
  - Light is guided trough fiber-integrated diffraction grating two times
- **No coupler and minimal routing required for extra tight space**
- **Simplified design for ease of production and robustness**

XMA FBG-Interrogator

Bi-Directional Build-Up



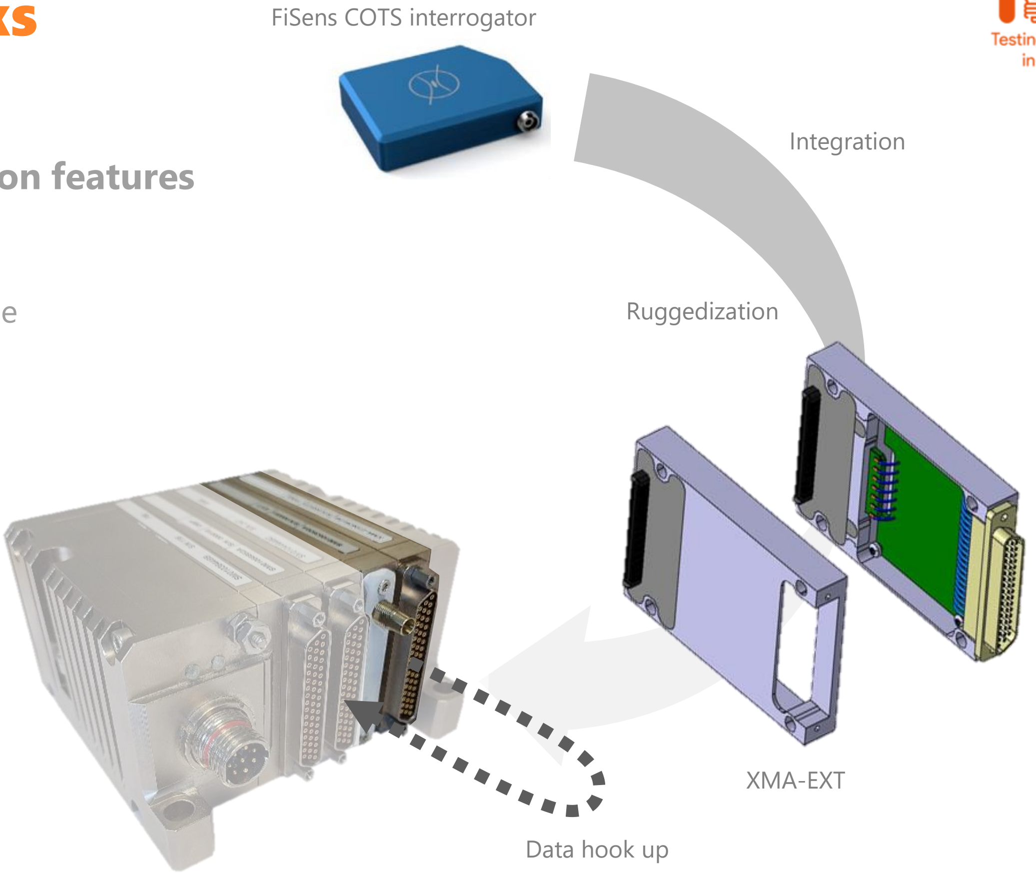
Spectrum of 25FBG at 850nm



Integration in a modular data acquisition unit

Integration in XMA stacks

- **Leveraging XMA « COTS » customization features**
  - XMA-PRO & EXT modules
  - Electrical and mechanical XMA ICD compliance
  - Electrical powering
- **Connector/front panel adaptation**
  - Fiber optic connector
- **XMA-FBG prototype module**
  - 50 x 80 x 20mm
  - Additional module required to acquire digitalized measurements



Integration in XMA stacks

- **Benefits of modularity**
  - XMA-FBG module stackable with other module types
    - Resistive, piezoelectric, capacitive, inductive, digital, video,… acquisitions in addition to FBG measurements
  - Multiple XMA-FBG modules capability in a single stack
    - Scalable solution
  - Different form factor
    - XMA-CORE8, XMA-CORE16, XMA-ROTOR,…

XMA-CORE8 with
- 1 FBG interrogator
- 2 other modules

XMA-CORE8 with
- 4 FBG interrogators
- 2 other modules

XMA-ROTOR with
- 2 FBG interrogators
- 1 wireless module
- 6 other modules

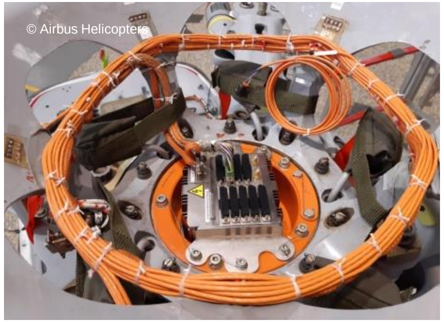
Perspectives

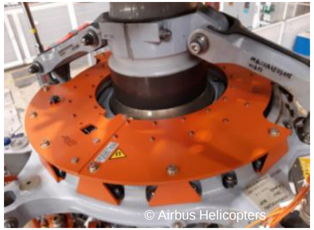
- Many use cases identified for compact & modular FBG interrogator in aerospace domain






- Upgrade wireless helicopter rotorhead instrumentation to offer fiber sensing blade monitoring





THANK YOU!

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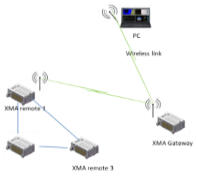
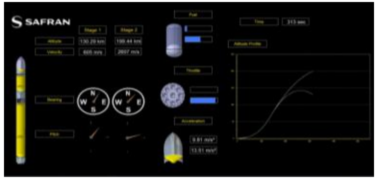
TRAINING

Valentin BELAUD

Innovation and Business Dev Manager

Safran Data Systems





Testing & Training in Motion

On-Board Processing How and why processing is now mandatory in your FTI ?

023

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Introduction

From saving bandwidth to calculation result in real-time, processing as near as possible of the measure brings your Flight Test Instrumentation up to a next level.

Interconnected devices, synchronized ethernet network and powerful embedded processors allow to start the data analysis way before its transmission to the ground. Thus it speeds up the test campaign, saves time and enhances the safety of the pilote plus his test vehicle.

Agenda

1. Processing levels in FTI

1. Processing levels in Flight Test Instrumentation (FTI)

Testing & Training in Motion

- **“Processing” and “Real Time Processing”:**
  - **Processing** :
    - Application of an algorithm over one or more acquisitions (digital data or sampled analog signal) to produce derived parameters
  - **Real Time Processing :**
    - Application of a processing to the acquisition before its display, transmission or record, in order to ensure its availability during the test flight as a physical parameter would be

1. Processing levels in Flight Test Instrumentation (FTI)

- **“On-Board” and “Embedded”:**

  - **On-Board Processing:**
    - Application of a “Real Time Processing” to some acquisitions on-board the test aircraft
    - Generally performed by an on-board computer (OBC)

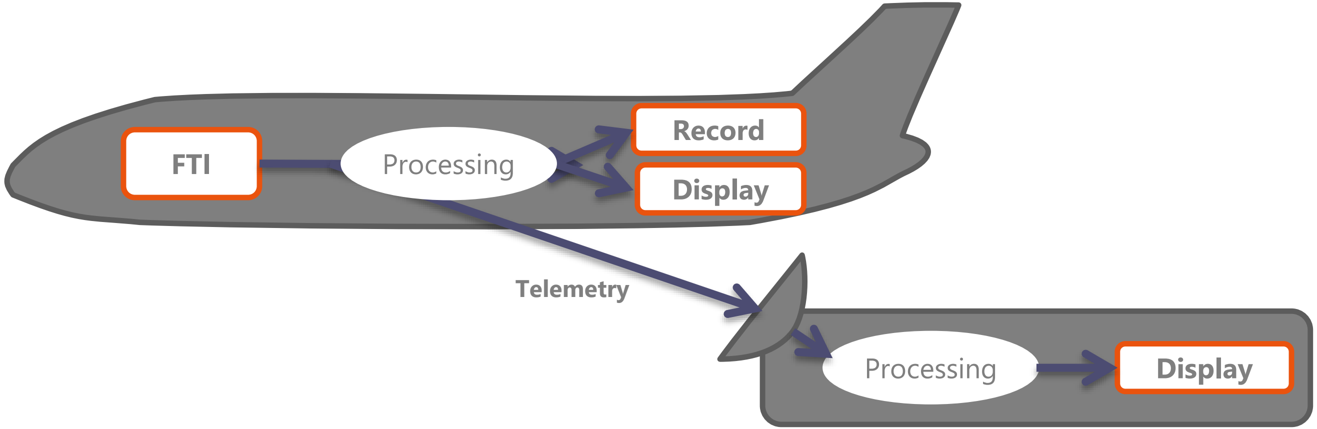
  - **Embedded Processing:**
    - Application of a processing to the acquisition inside the Data Acquisition Unit
    - Generally performed by an acquisition module itself or an on-board processing module inside a stack (OBP)

1. Processing levels in Flight Test Instrumentation (FTI)

Testing & Training in Motion

- **Real Time Processing is required to speed up data analysis to get the useful information during flight test and not after a post-processing phase.**

- **Real Time Processing can be performed either:**
  - On the ground, by processing the data received by telemetry
  - On-board the aircraft, by processing the data before its recording, on-board display or transmission to the ground



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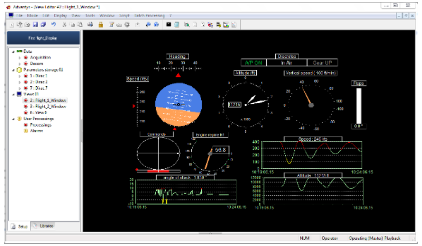
1. Processing levels in Flight Test Instrumentation (FTI)



- **Ground Real Time Processing**
  - **Can be performed by a Decoding/Decommutation software:**

1. Receive data in any format : Telemetry (IRIG106 Ch4, Ch7 ..), Ethernet protocol (IENA, IRIG106 Ch10, DAR) …
2. Apply processing
3. Transmit data to display and recording AND/OR use results as inputs to other processings

- **Display**
  - more relevant data in *Real-Time*
  - gain performance by transmitting useful data or even giving warning (pilot/engineers)

- **Recording**
  - more relevant data to analyze
  - speed up the flight test campaign

1. Processing levels in Flight Test Instrumentation (FTI)

Testing & Training in Motion

- **On-Board Real Time Processing**
  - **Can be performed by a Decoding/Decommutation software:**

    1. Receive data generally ethernet protocol (IENA, IRIG106 Ch10, DAR) from the ethernet network
    2. Apply processing
    3. Transmit data to display, recording and telemetry

- **Display**

- **Recording**

- **Telemetry** to send calculation results instead of raw parameter to save bandwidth

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Chapter 02

2. Why embedded processing in DAU ?

2. Why embedded processing in DAU ?

Testing & Training in Motion

- **Real-time processing can be superseded by embedded directly the processing <u>inside</u> Data Acquisition Units**

- **Gain in :**
  - **Latency**
  - **Data flow reduction**
  - **Form Factor**
  - **Lower Complexity**
  - **Parallelization**

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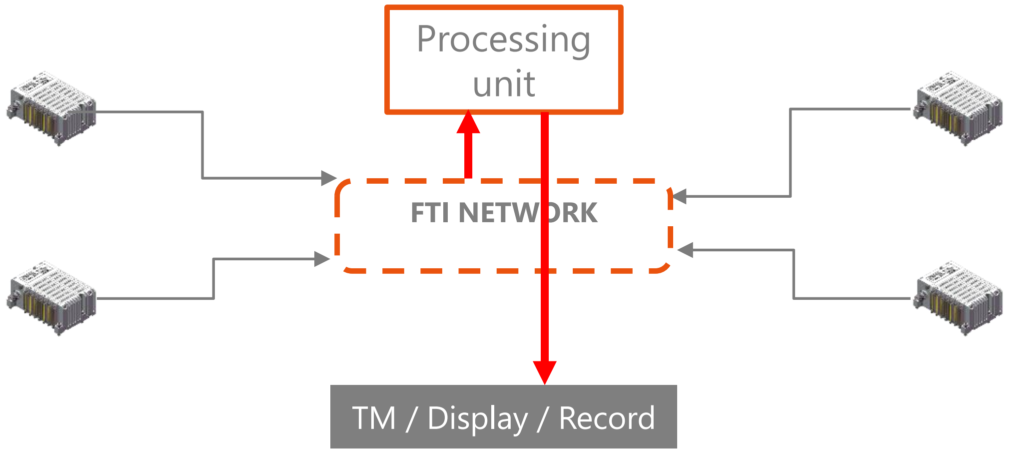
2. Why embedded processing in DAU ?

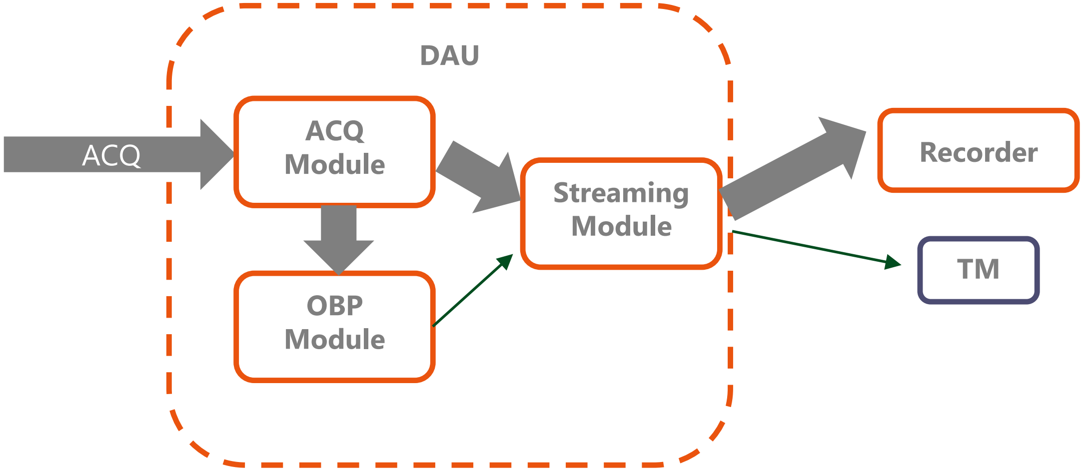
- **Latency**: Centralization of the processing allows to combine all acquisition of the FTI, but it introduces latency because a large amount of data go to one single processing unit



Latency :
- t1 encapsulation 1
- t2 network delay 1
- t3 de-encapsulation 1
- t4 processing delay
- t5 encapsulation 2
- t6 network delay 2
- t7 de-encapsulation 2

2. Why embedded processing in DAU ?

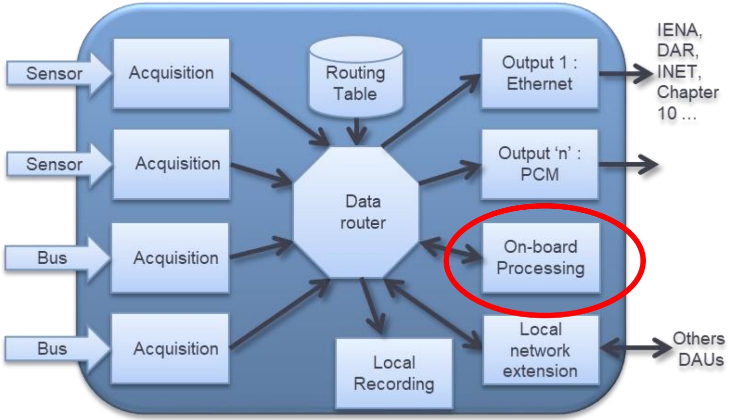
- **Data flow reduction**: especially for Telemetry down-link, processing data inside Data Acquisition Unit reduces the telemetry data bandwidth to only the useful data

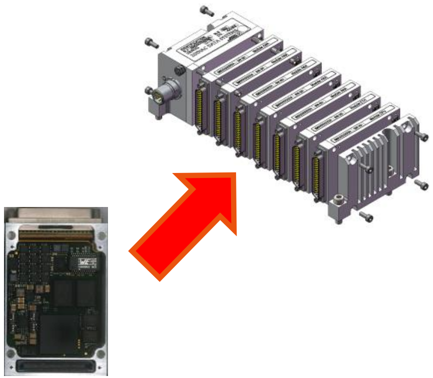


2. Why embedded processing in DAU ?

- **Form factor**: not all flight test cases can host an on-board workstation or an on-board computer.

- Embedding processing in a Data Acquisition Unit allows to meet constraint system requirements





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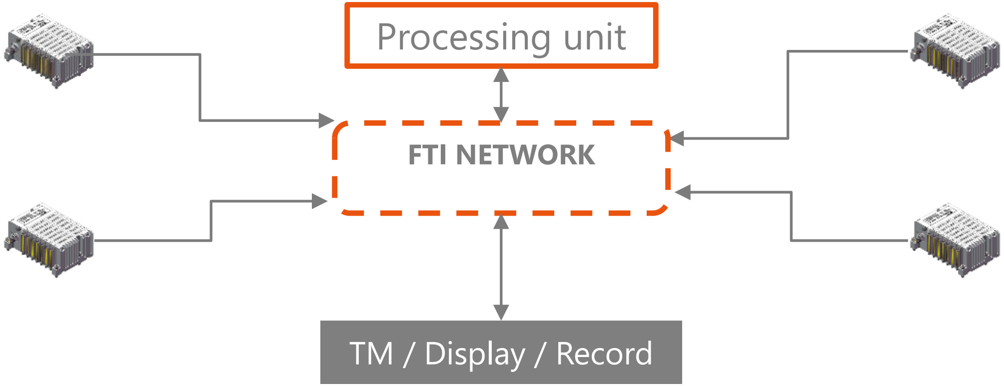
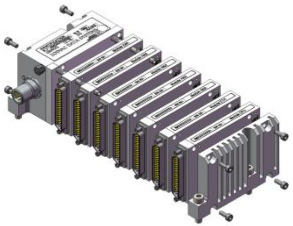
2. Why embedded processing in DAU ?

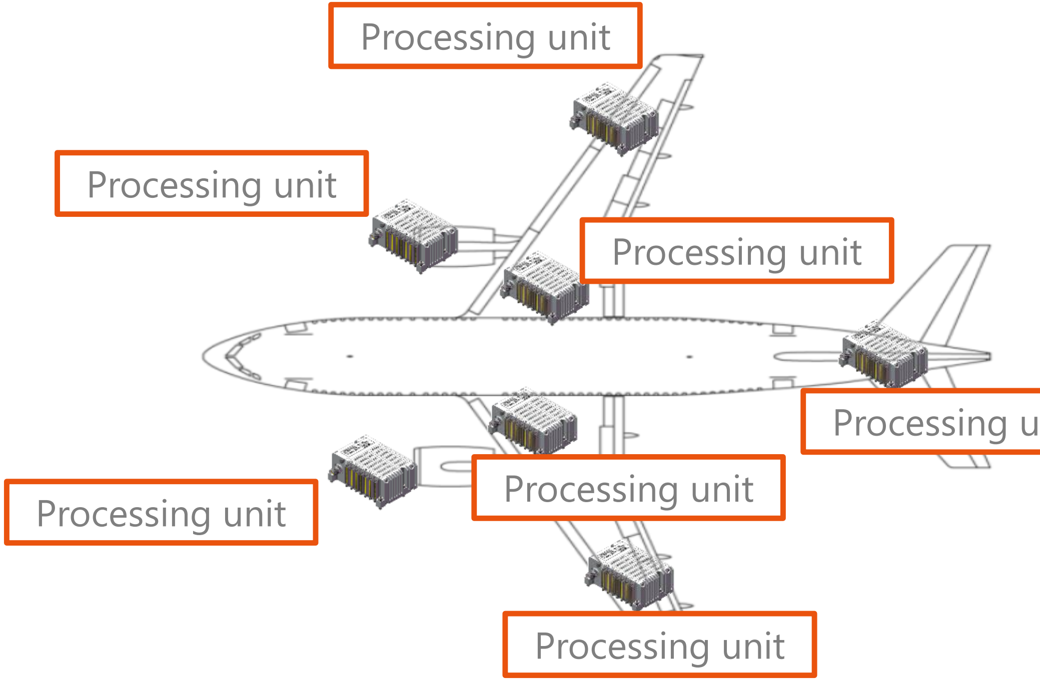
- **Lower complexity**: by performing processing inside Data Acquisition Unit, the system requires less “inter-connection”, less configuration (only DAU is configured)
  - **Processing is “just” an additional module!**





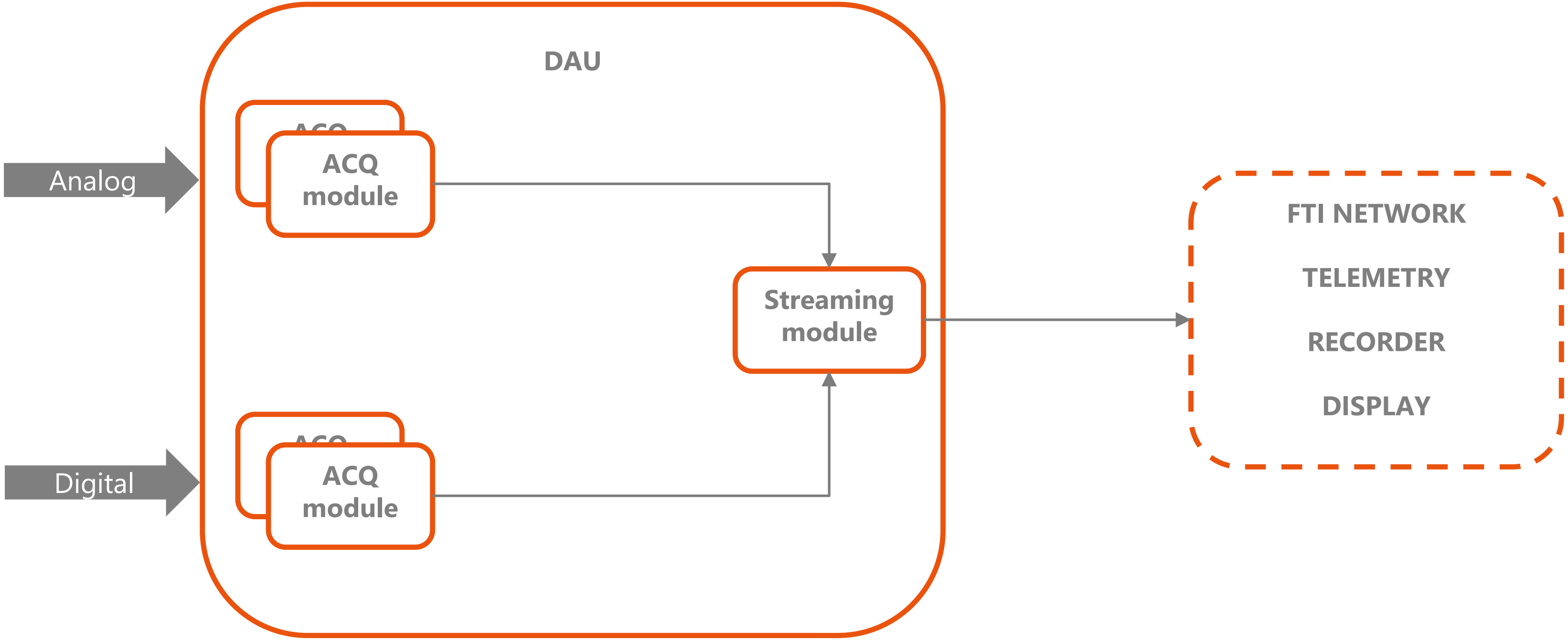
2. Why embedded processing in DAU ?

- **Parallelization**:
  - spreading the computation inside all Data Acquisition
  - Expand the processing power



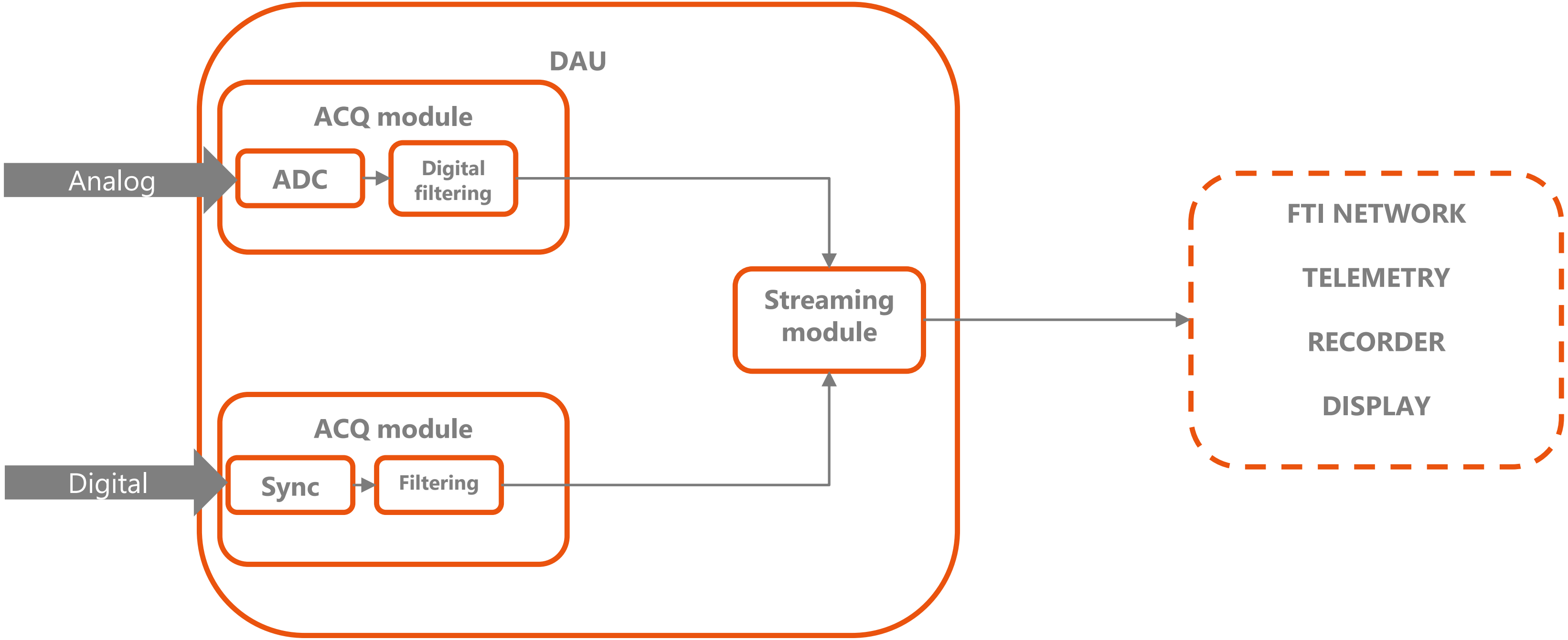
2. Why embedded processing in DAU ?

- Legacy data acquisition chain



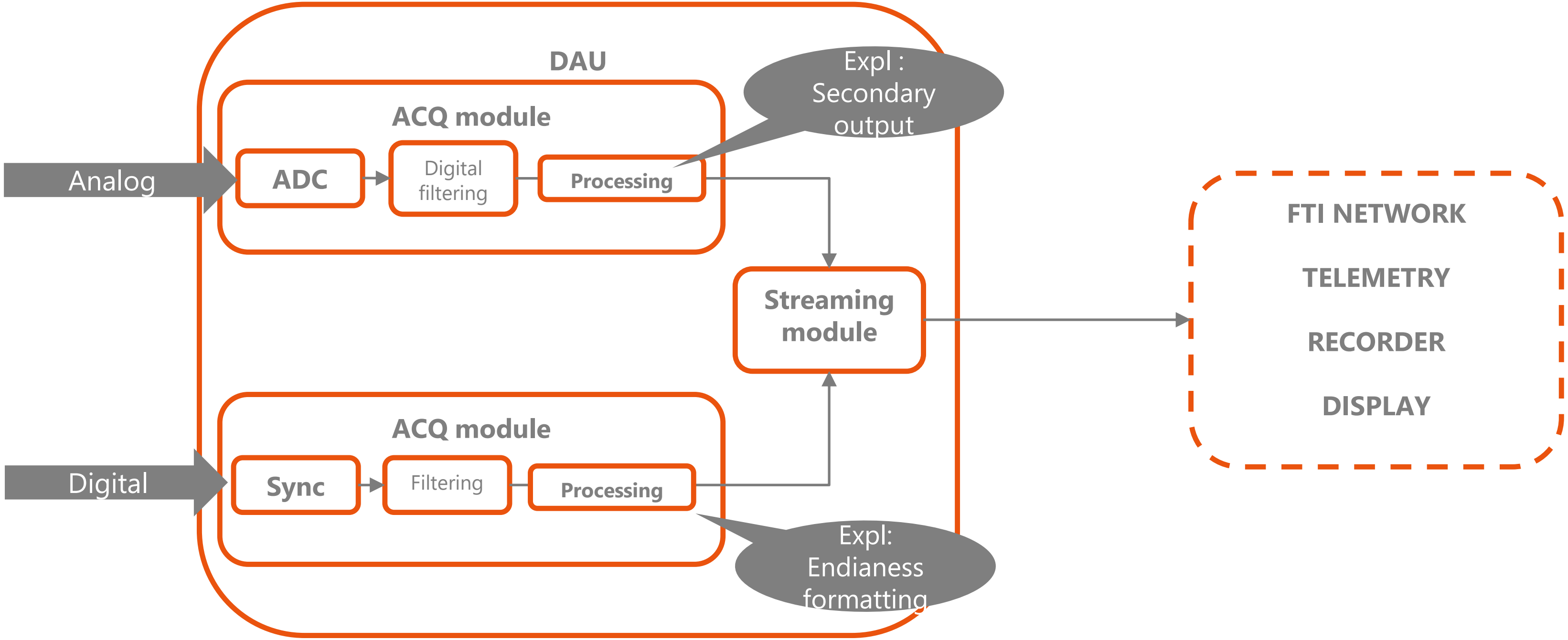
2. Why embedded processing in DAU ?

- First level of embedded processing ➔ filtering capabilities



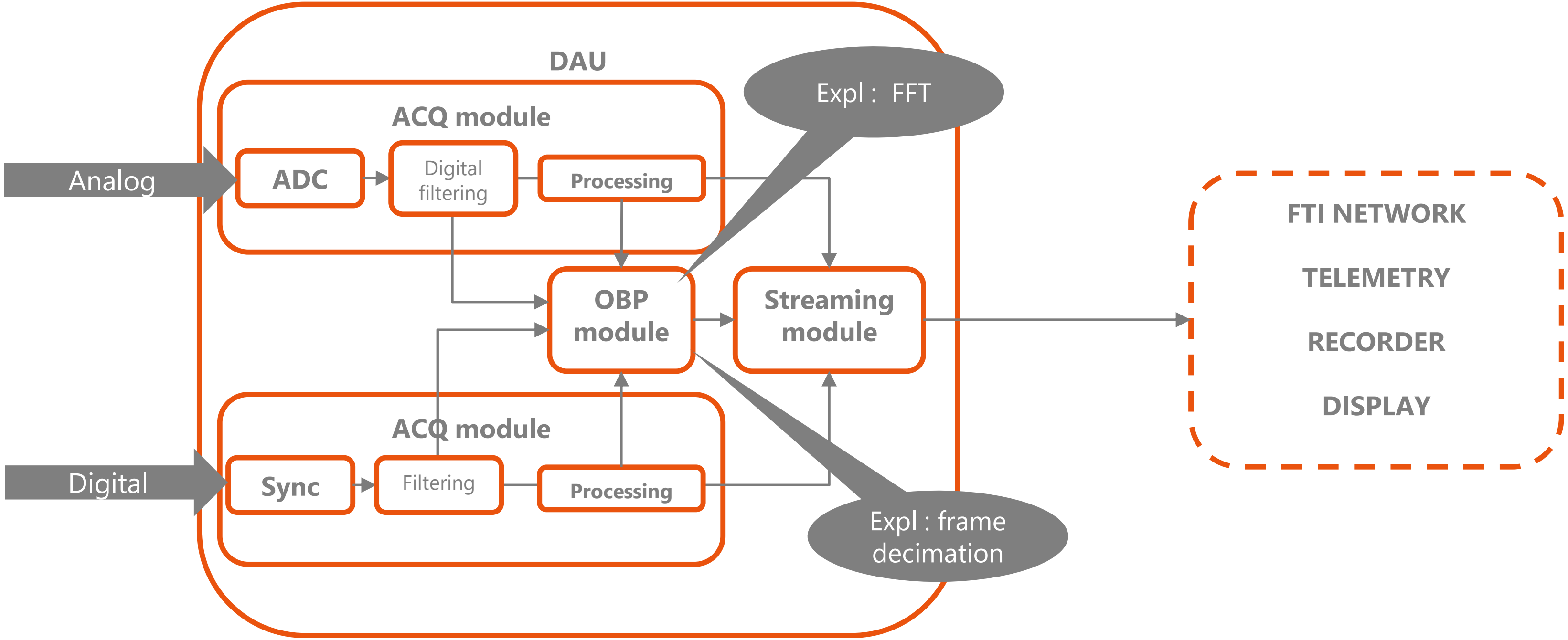
2. Why embedded processing in DAU ?

- Second level of embedded processing → directly in the acquisition module



2. Why embedded processing in DAU ?

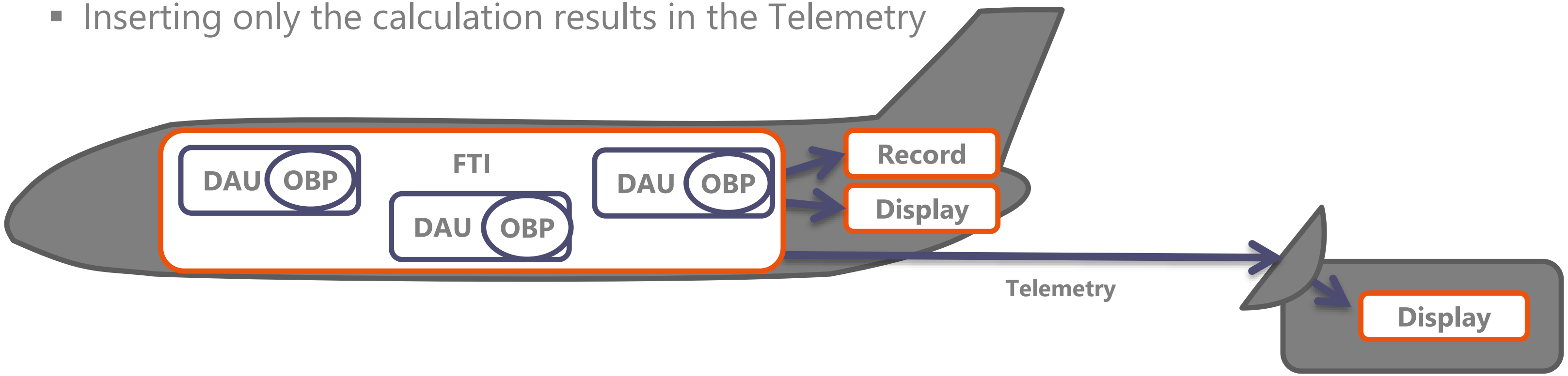
- On-Board Processing module to add a powerful calculation unit in the stack



2. Why embedded processing in DAU ?

- **Increase the filtering capabilities**
  - to stream only the useful data and optimize the network bandwidth
  - To select the useful payload to insert in the Telemetry

- **Processing directly in the DAU via OBP module and even in the acquisition modules**
  - Allowing the user to distribute the processings across the devices to optimize latency
  - Inserting only the calculation results in the Telemetry



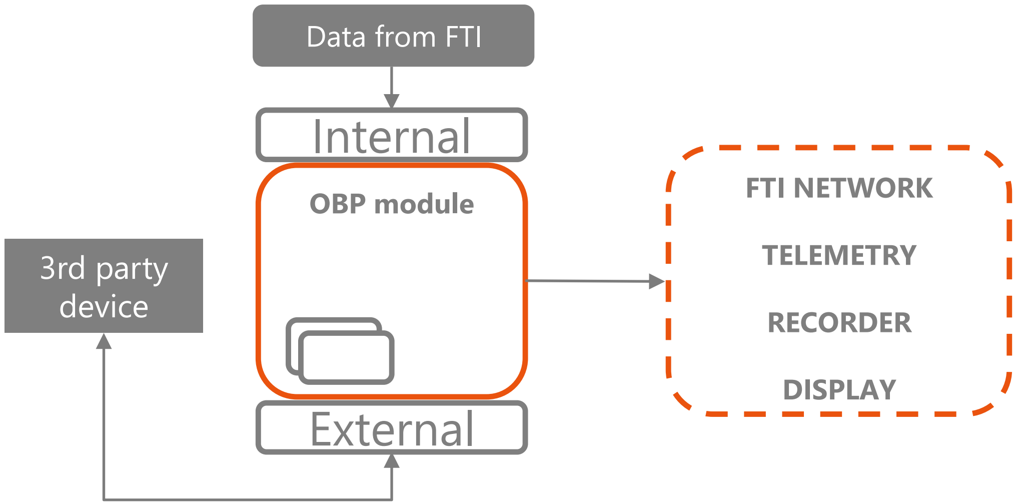
2. Why embedded processing in DAU ?

- **Using OBP module not only to process data …**

… but to be used as a 3rd party gateway:

- **Control** other devices
  - Send command
  - ON/OFF
  - Sequenceur
  - Safety trigger

- **Communicate**
  - Custom format to acquire / emit
  - Switching mode to another

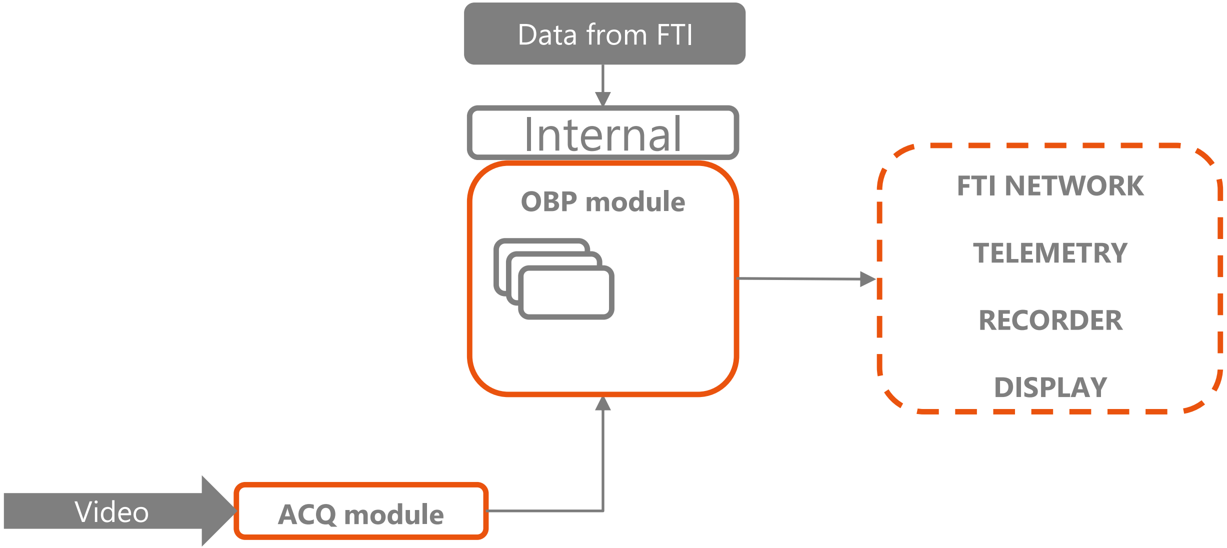


2. Why embedded processing in DAU ?

- **Using OBP module not only to process data …**

… but to use memory/processing capability to:

- **Buffering**
  - Differed parameter for telemetry
  - Statistical analysis
- **Video processing**
  - Compression
  - Formatting



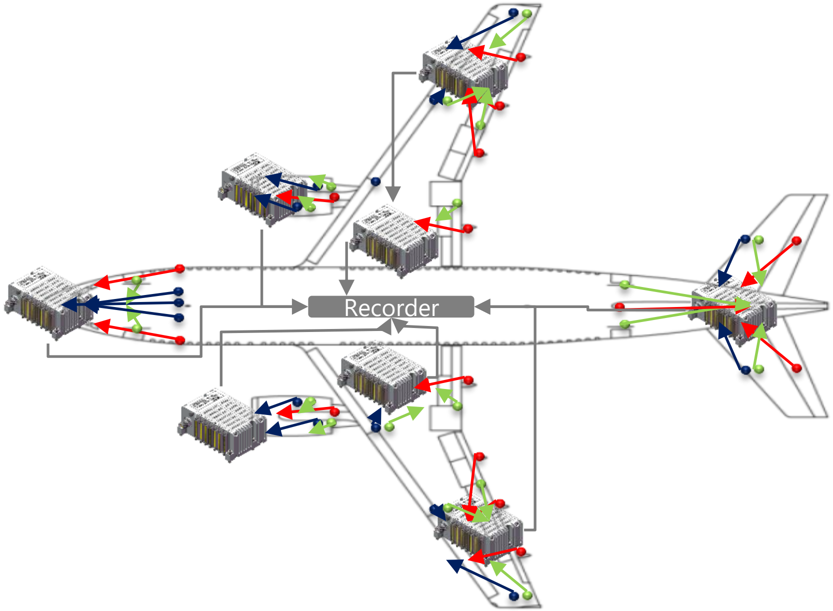
Chapter 03

3. FTI Data & Use Cases

3. Flight Test - Data & Use Cases

- **Civil or Military A/C**
- **Manned / Unmanned**

  - Data traffic from avionics buses ↗
  - Number of connected devices ↗
  - Test Campaign duration ↘



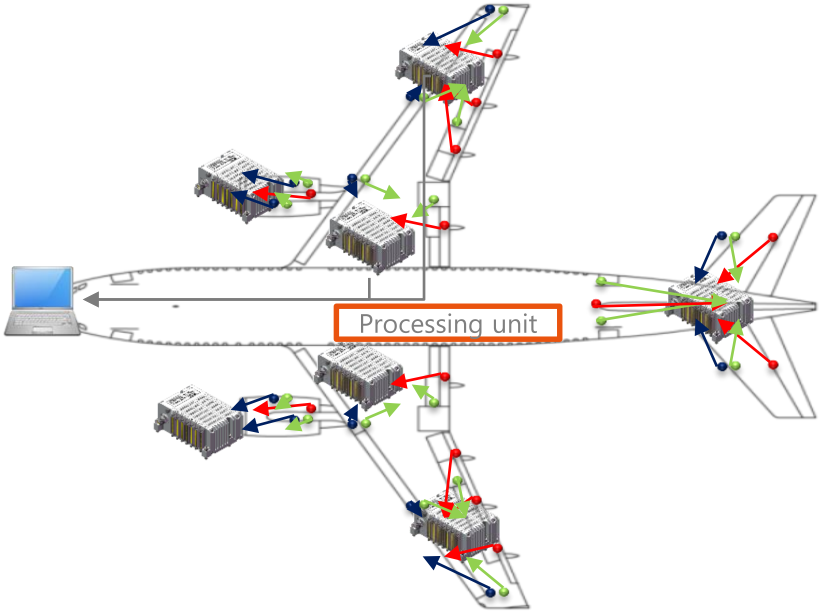
- **Data needs to be processed to meet the challenge of future FTI by optimizing the TM bandwidth with useful data and pre-analyzing the huge amount of data**

3. Flight Test - Data & Use Cases

- **Example 1 : Flutter effect**
  - Processing the data closer to the measures
  - Give the info to the pilot w/o ground analysis
  - Reducing the loop reaction time

Safety

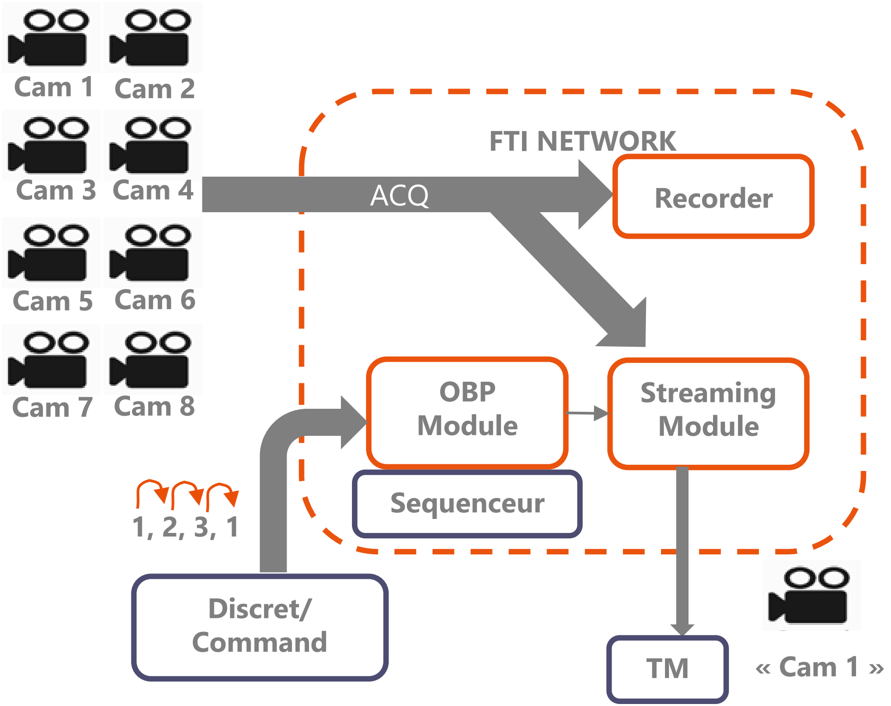
Exploring the flight domains



Flutter is a dynamic instability of an elastic structure in a fluid flow, caused by positive feedback between the body's deflection and the force exerted by the fluid flow.

3. Flight Test - Data & Use Cases

- **Example 2 : Video switch for Telemetry (TM)**
  - **IP cameras** in the network stream to the FTI network
  - Processing unit
    - controls the streaming module by using **TM format switching**
    - select one or several cameras for TM stream
  - Control can be
    - External : Command or Discret/Event
    - Internal : **Sequencer**

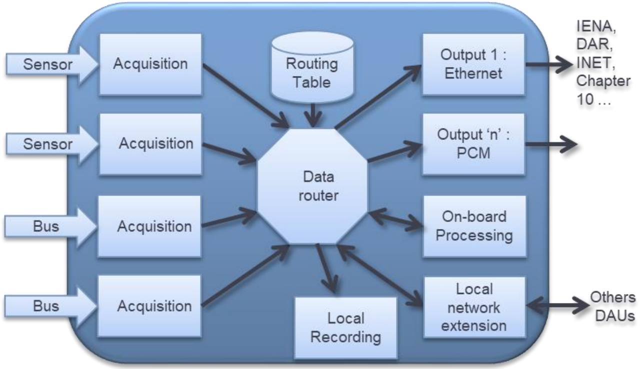


Chapter 04

4. Missile&Launcher - Data & Use Case

4. Missile & Launcher – Data & Use Cases

- **Missile&Launcher bring new reasons to process data**
  - Vehicle is unlikely recovered so the data recorded
  - Very few test flights/launchs
  - Bandwidth / link budget more and more challenging
  - SWaP always a big constraint

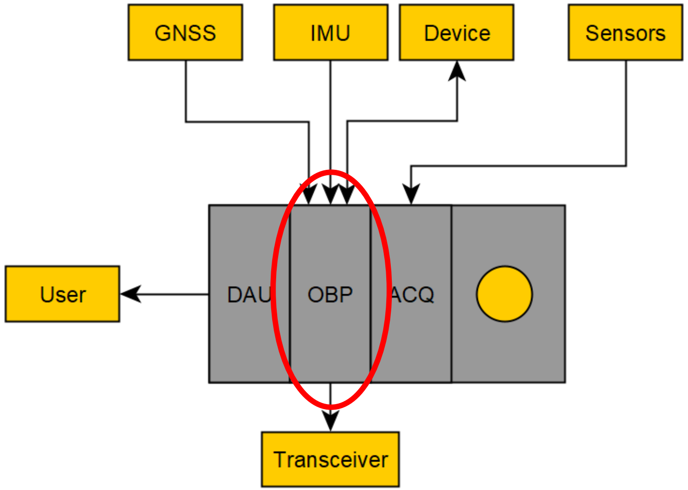


On-Board Processing

- save volume & data
- enhance data use

4. Missile & Launcher – Data & Use Case

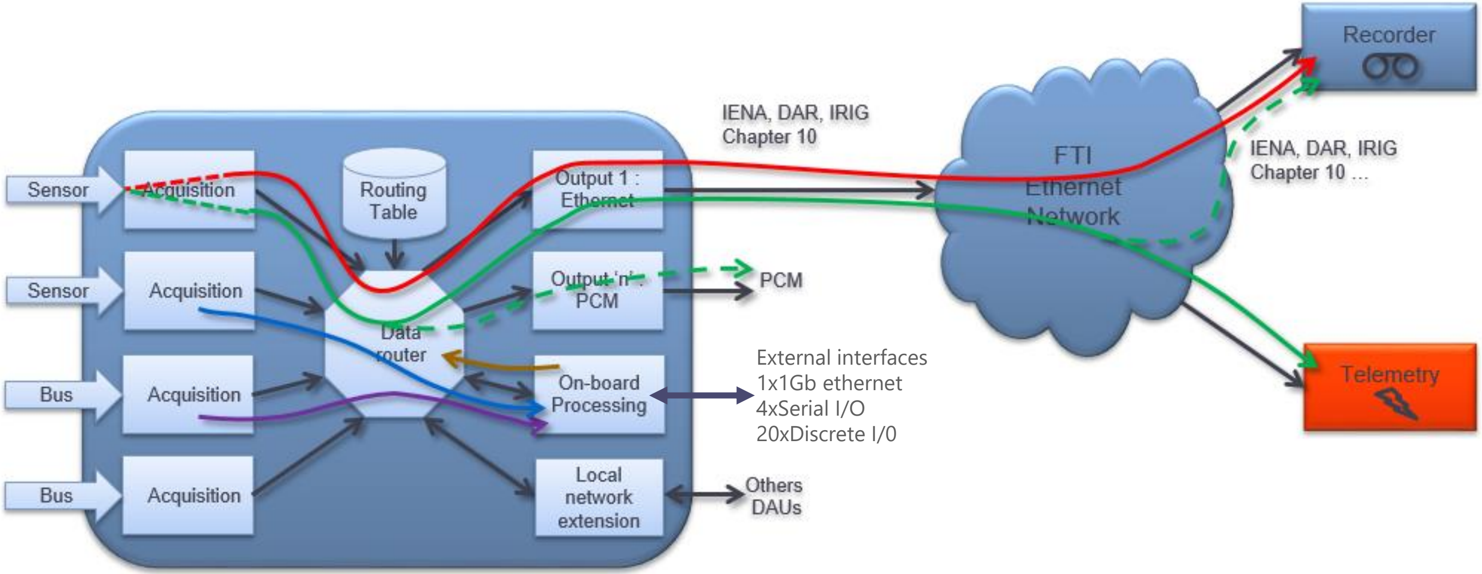
- **Example : DAU controller / TM gateway**
  - Hybridization GNSS + IMU
  - Packet telemetry formatting/housekeeping telemetry
  - Buffering
  - Flight sequenceur
  - Controlling home made device / opportunity payload



Chapter 05

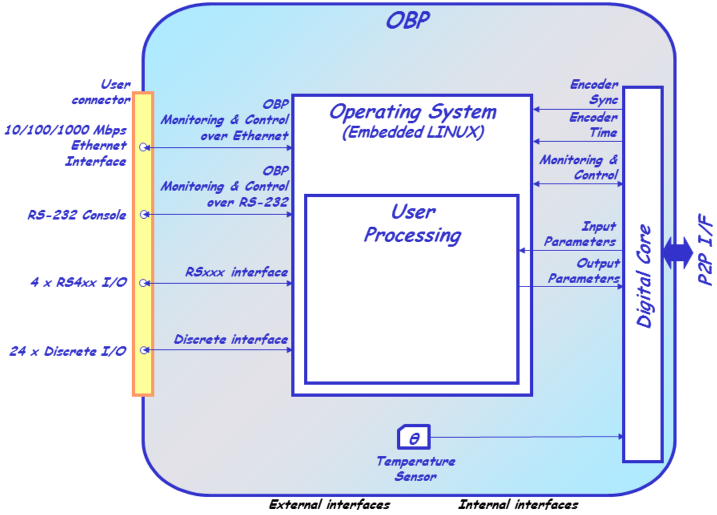
5. Embedding processing within a COTS module – OBP module

5. Embedding processing within a COTS module – XMA-OBP



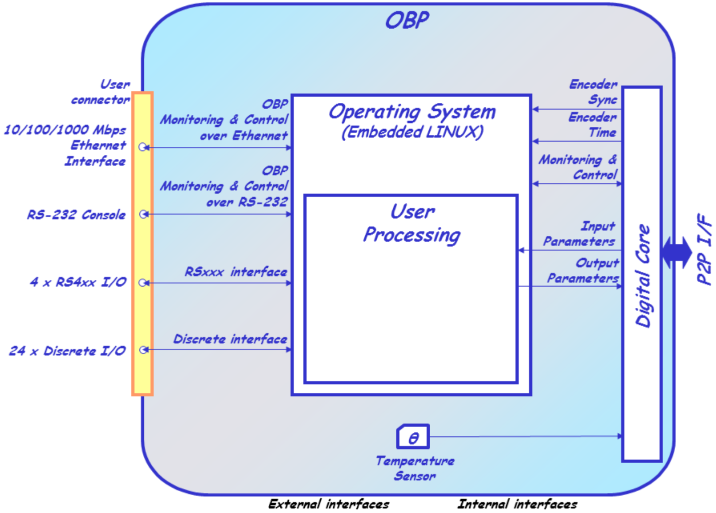
5. Embedding processing within a COTS module – XMA-OBP

- **Processing on data stream @ DAU level:**
  - enhanced filtering, extraction of parameters, formatting, calculations …
- **Heterogeneous computation**
  - run algorithms implying both analog and digital data
- **Real time management**
  - timers, interruptions
- **Processing Ctrl & Debug**
  - Ethernet and serial console



5. Embedding processing within a COTS module – XMA-OBP

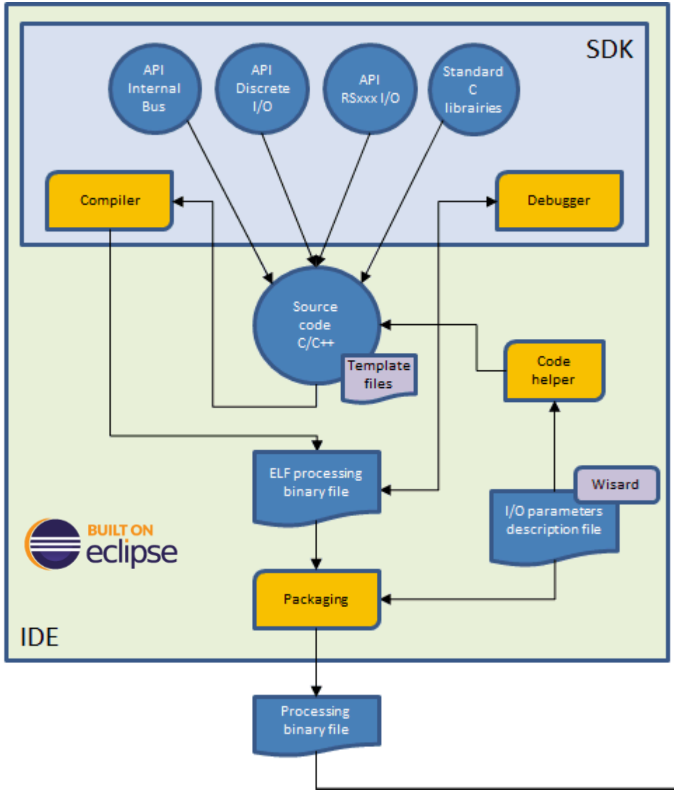
- **Basic capabilities :**
  - Acquiring any data from XMA network
  - 20 (up to 24) programmable discrete I/O
  - 4 RS (2 Synchronous RS422 or 4 async RS232/4XX)
- **Advanced capabilities**
  - 1 10/100/1000 Ethernet fully programmable
- **User interfaces**
  - 1 10/100/1000 Ethernet : debug mode, FTP, SSH, Syslog
  - RS232 console port, Ethernet: debug mode, system log, trace/debugging probe



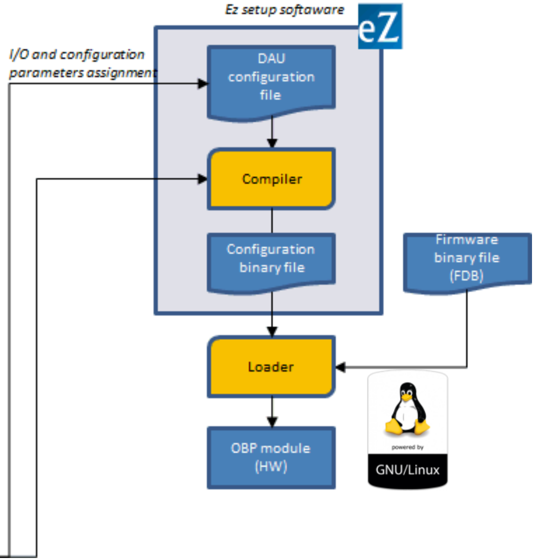
5. Embedding processing within a COTS module – XMA-OBP

- **Processing characteristics / Calculation performance:**
  - Computing power of ARM processor, dual core @667 MHz / Zync 7020 SoC
  - 1665 DMIPS/Core ➔ Total: 3330 DMIPS (raw core performances)
  - NEON & Single / Double Precision Floating Point for each processor
  - Cache : L1 (32 KB Instruction, 32 KB Data per processor), L2 (512 KB)
  - External Memory: 512 to 2048 MB (shared with OS)
- **SDK (Software Development Kit) provided**
  - API library (Application Program Interface) : common core access, transmission and reception of input/output parameters, external interfaces management
- **IDE (Integrated Development Environment) validated (Eclipse Neon 3)**
  - Pre-configured compiler and debug paths environment
  - Automatic generation of the IO parameters description file and processing package management
  - Debug mode, Online help, code templates and code helper, creating of static and dynamic libraries.

5. Embedding processing within a COTS module – XMA-OBP



Two integrated workflows



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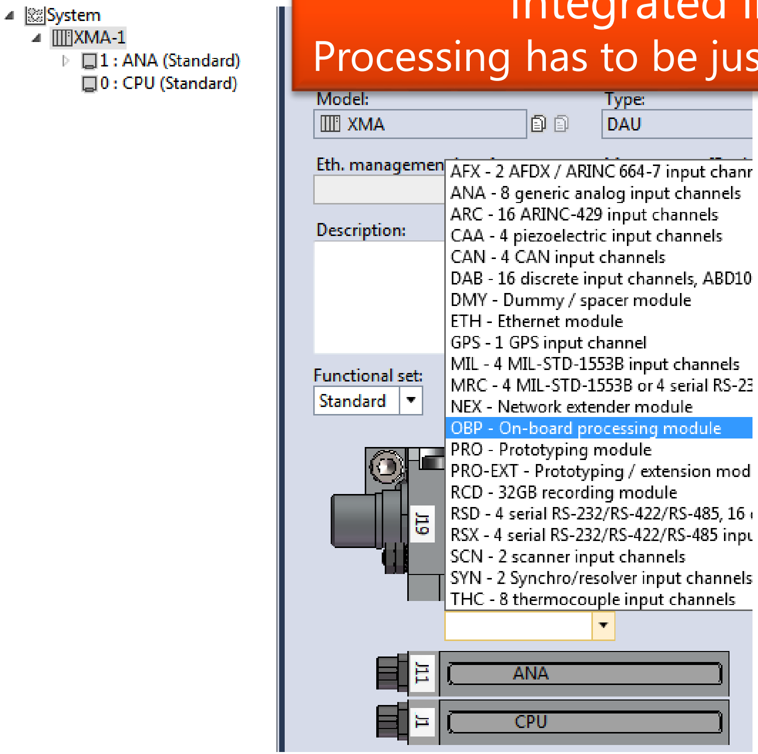
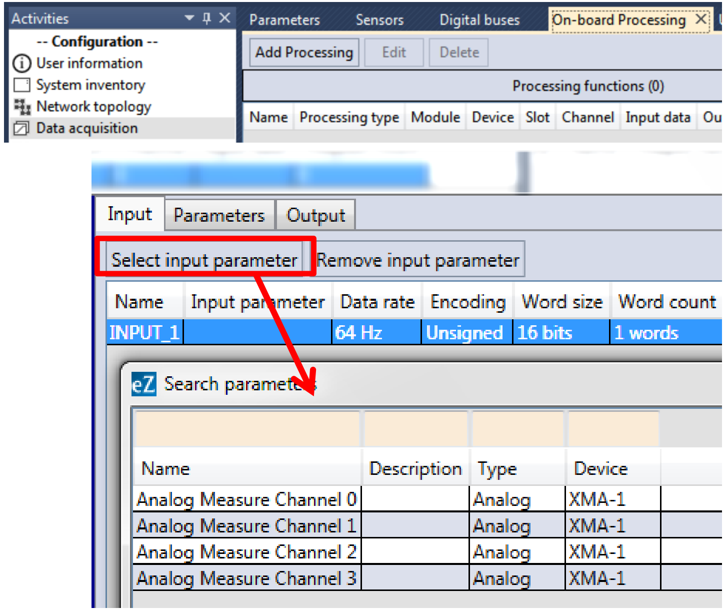
5. Embedding processing within a COTS module – XMA-OBP

Integrated in the DAU Software Suite

Processing has to be just like another module in the Flight Test





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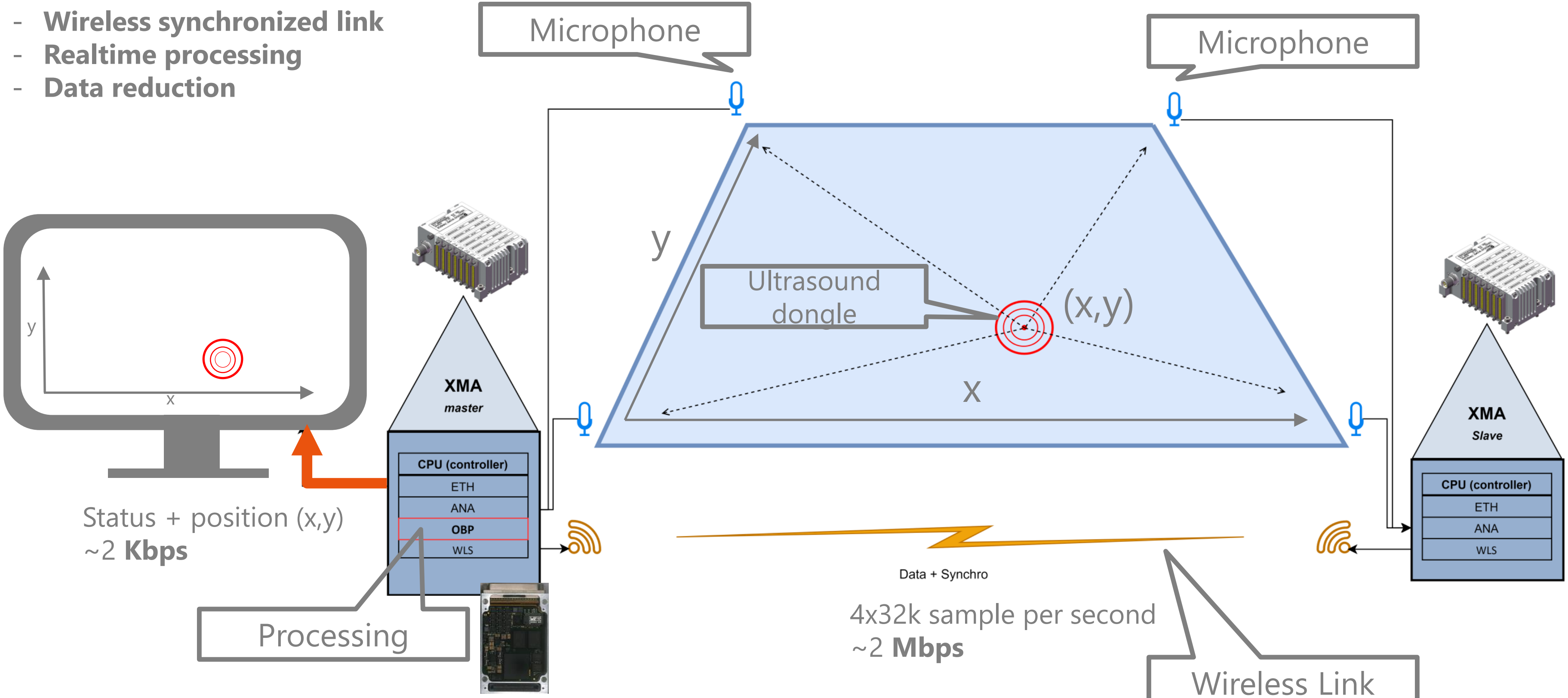
Demo – Multilateration with wireless synchronization

- High sampling rate data acquisitions
- Embedded processing to send only calculation results in the telemetry
- Using XMA wireless capacities
- Applied to a source localisation use-case

OBP Use-Case: Multilateration Demo

- **Wireless synchronized link**
- **Realtime processing**
- **Data reduction**



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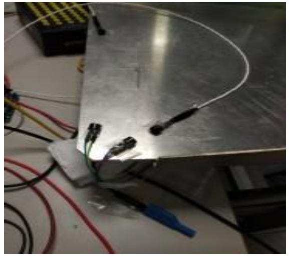
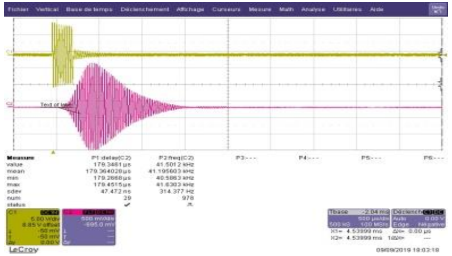
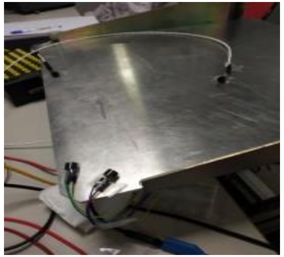
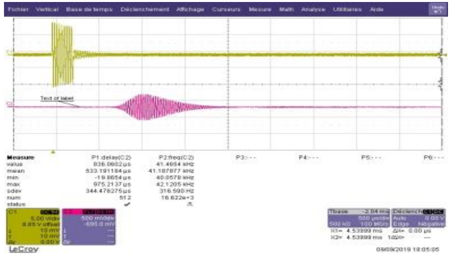
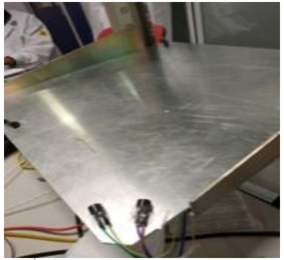
OBP Running Application: multilateration algorithm

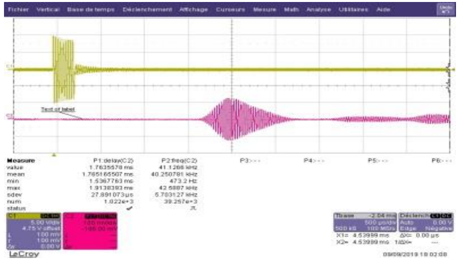


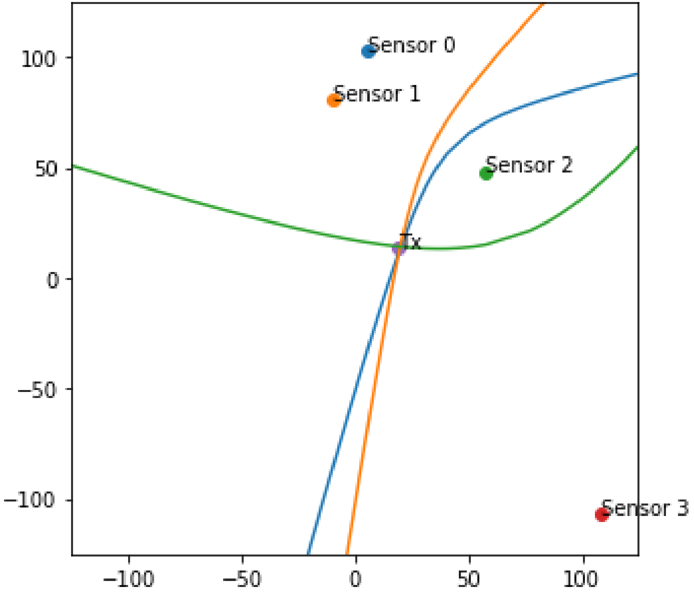












THANK YOU!

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TRAINING

Pierre BASTIE
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Testing & Training in Motion

Range of the future: how the range architecture is evolving?

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Agenda

01

Range of the Future

02

Recall on current range ground TM architecture

03

3 solutions to address Range of the future

04

Hands-on & Q/A

Range of the future
Origin, Concept and Objective

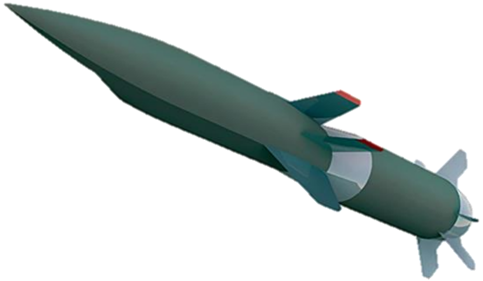
A Space Force Strategic Intent

- **Support more frequent launches**
  - Modernization of the 45th (Patrick/Canaveral) and 30th (Vandenberg) Space Wings to keep up with the increased launch demand from USG, Commercial customers and exploration missions.
  - Space Wing renamed Space Launch Delta -> Space Port
  - Objective is to significantly increase the yearly rate:
    - 10 launches in 2010 to 35 in 2020, aiming for 48 (“Drive to 48”)

- **How ?**
  - Align 45th and 30th range procedures and policies
  - Broad spectrum: Radar, TM, weather, Safety, Collision, Maritime, Air Traffic,…
  - Deploy Autonomous Flight Safety System (AFSS) for all launches
    - Ground based architecture reduced (e.g. no radar)
    - Mandatory by Oct. 1st 2025
  - Network based communication architecture (from wired lines)
  - Plug & Play with 3rd party / User equipment
  - Mobile tracking assets
  - Support several launch activities at once
    - Pre-launch ground testing in conjunction with a launch
  - Agile, Reconfigurable (from 3 days to 3hrs) and Scalable equipment

Range of the Future for DoD test ranges

- **Range extension**
  - Need to cover a larger area
    - Increasing number of remote TM stations (ground based) – the earth is round !
    - Shipborne and airborne TM stations possible for better LOS
    - Explore Space-based (GEO /LEO) relay solution
  - Need of real-time Telemetry for Flight Safety
    - Loss of TM coverage can lead to target termination
    - Off-line station needs to be connected to the range network -> TMoIP
    - Real-time selection between stations -> BSS
- **More test articles that go faster**
  - Test scenario with more test articles at once (15+)
    - Duplicating parabolic antennas has its limit
    - AESA (phased-array) solution is a better fit…in most cases
  - With faster test articles
    - Could be beyond mechanical capability of parabolic antenna -> AESA
  - More Telemetry streams with higher bit rates
    - Efficient waveforms and agile / reconfigurable TM equipment
    - Ultra Wideband RF recording to offload realtime demodulation requirement -> RF recording
    - Increase demodulator density into TM receiver -> Multi-channel TM processor



Range of the Future for DoD test ranges (Cont')

- **Encrypted Telemetry link**
  - Realtime source selection needs to be performed without pre-processing the TM link (ie Sync. word)
  - Introduction of BSS with IRIG- DQE/DQM

- **Relying on robust range communication Network**
  - TM products need to be network centric with native IP interface

  - Once RF signal is digitized (at Rx), signal flow could be IP based ONLY
    - From RF over fiber to RF over IP -> Virtualized Ground station
    - Without compromising the strict range latency requirement

  - Removal on any custom HW for PCM interface
    - Migration from PCM based KG decryptor to Ethernet based KG

- **Ground recorder becomes network IP stream recorder**
  - ch10 format remains exchange format
  - Always possible to reconstruct the analog signals post-mission

- **Solutions foreseen**
  - Different level of maturity and availability
  - Brought by new IRIG106 standards and/or the industry initiative

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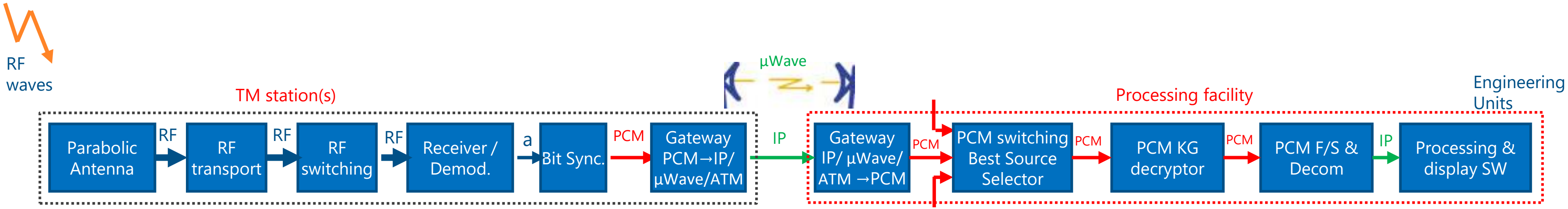
Range TM architecture
Legacy and examples

Vocabulary

- Few definition to insure common understanding
  - Test Article: platform being monitored (fighter, helicopter, UAV, missile, rocket, …)
  - "BLACK": indicate that the telemetry signal is not "clear" because it is still encrypted
  - "RED": indicate that the TM signal is clear either because it is not encrypted or it has already been decrypted
  - Telemetry station: site typically outside the DoD base (ie remote) but within the "range" that tracks the test article, and captures (ie record) the "Telemetry". Station can be fixed (mountain peak, tower…), mobile / transportable (trailer, skid,…), shipborne (boat off-shore) or airborne (chase A/C). The processing typically goes until the baseband (analog / PCM) level and all data is BLACK. Most of the time, the station is "connected" to the DoD base through range network so data can be shared in realtime but sometime, it is not (called an "offline" station).
  - Processing facility (also called Data Reduction center, Mission rooms..): building typically within the boundary of the DoD base (so more secured) where all the Telemetry station signals are received in realtime to deliver decommutated parameters (EU) to the flight test engineers. Typical processing functions include Selecting the best source, Decrypting and Recording the data, Feeding it to each mission rooms (one mission per test article, hence multiple rooms to accommodate multiple test articles at the same time).
  - Airframe Vs Missile: Though real-time decommutated parameters through Telemetry are used for safety of flight in both cases, it is mainly true for missiles for Flight Termination (those TM info is one source for the Safety officer to Terminate or not a mission). Contrarily, real-time parameters for airframe flight tests are used by engineers inside the TM room to analyze the data and move to the next certification testing; this is not the case for missiles (done post-mission)

DoD range TM architecture : functional block diagram

- Processing TM from RF waves to Engineering Unit parameters
  - > Successive functions as shown below
  - > Function location depend with each range architecture but typically split across 2 main locations
    - Telemetry station(s) – several remote site(s) off-base, can be maned or unmanned. “BLACK” level
    - Processing facility – on-base, where Program engineers' seat (in individual TM room). “RED” level



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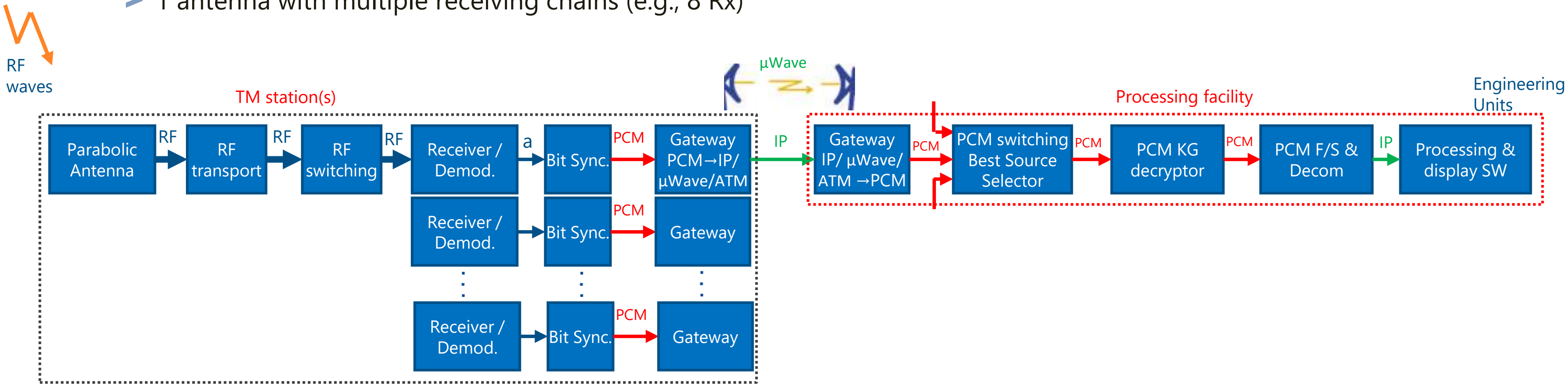
- TM station use cases
  - 1 antenna with multiple receiving chains (e.g., 8 Rx)



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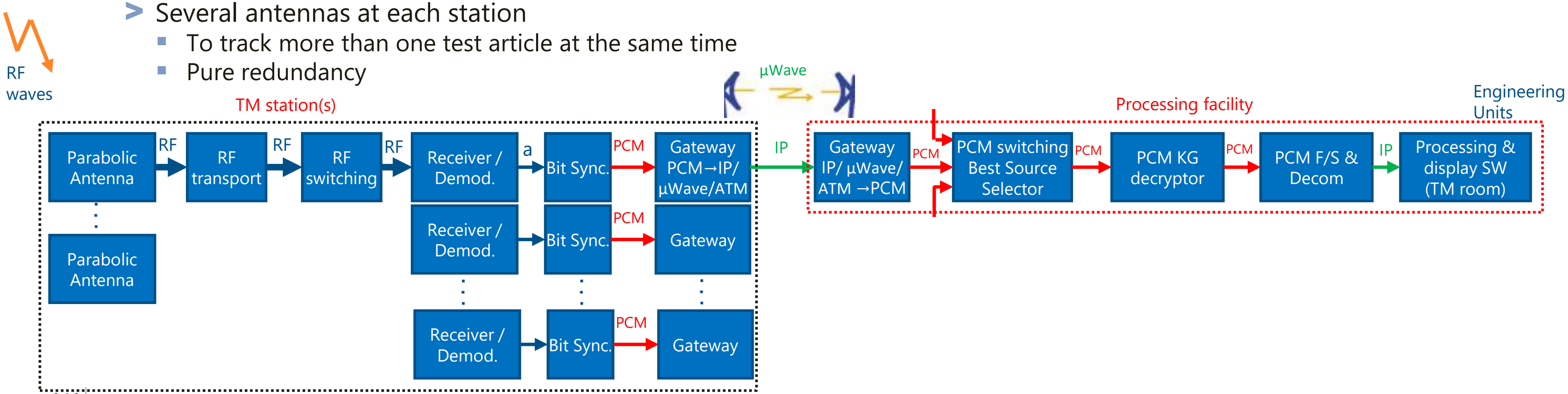
- TM station use cases
  - 1 antenna with multiple receiving chains (e.g., 8 Rx)
  > Several antennas at each station
    - To track more than one test article at the same time
    - Pure redundancy



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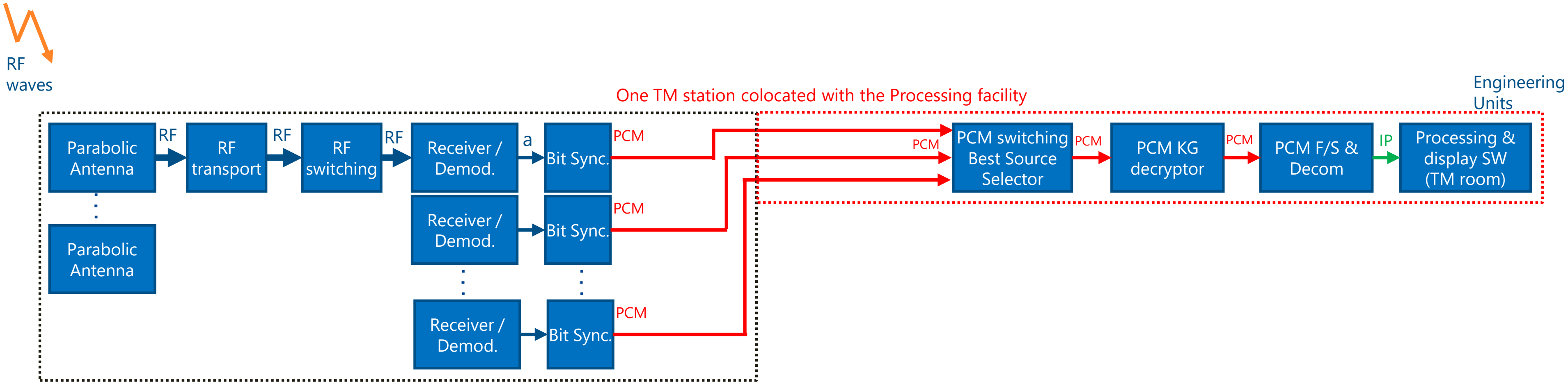
DoD range TM architecture : functional block diagram

- **Simplified architecture**
  - > One standalone TM station co-located with the processing facility
    - Direct PCM connection between receiver and the processing system



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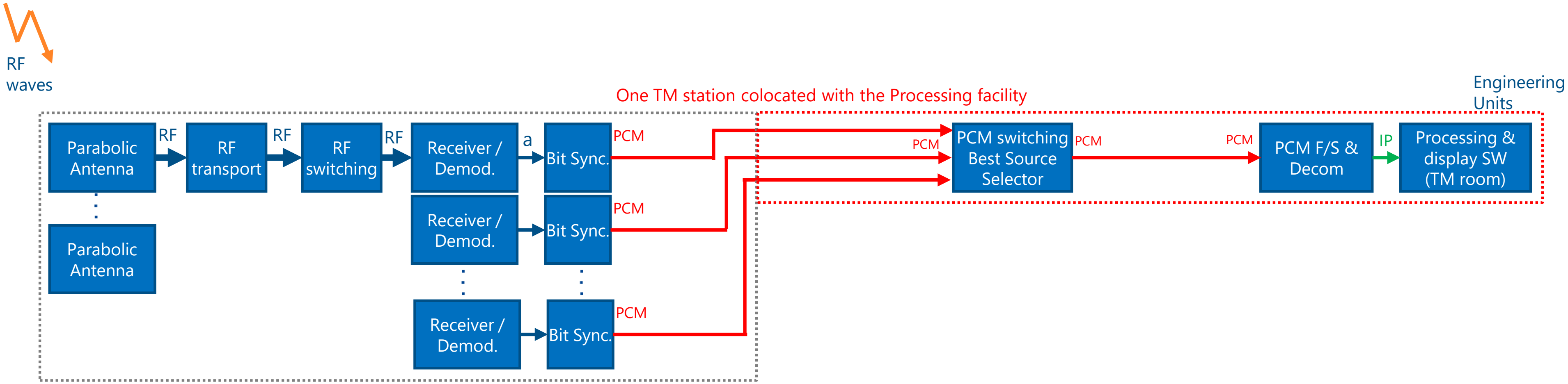
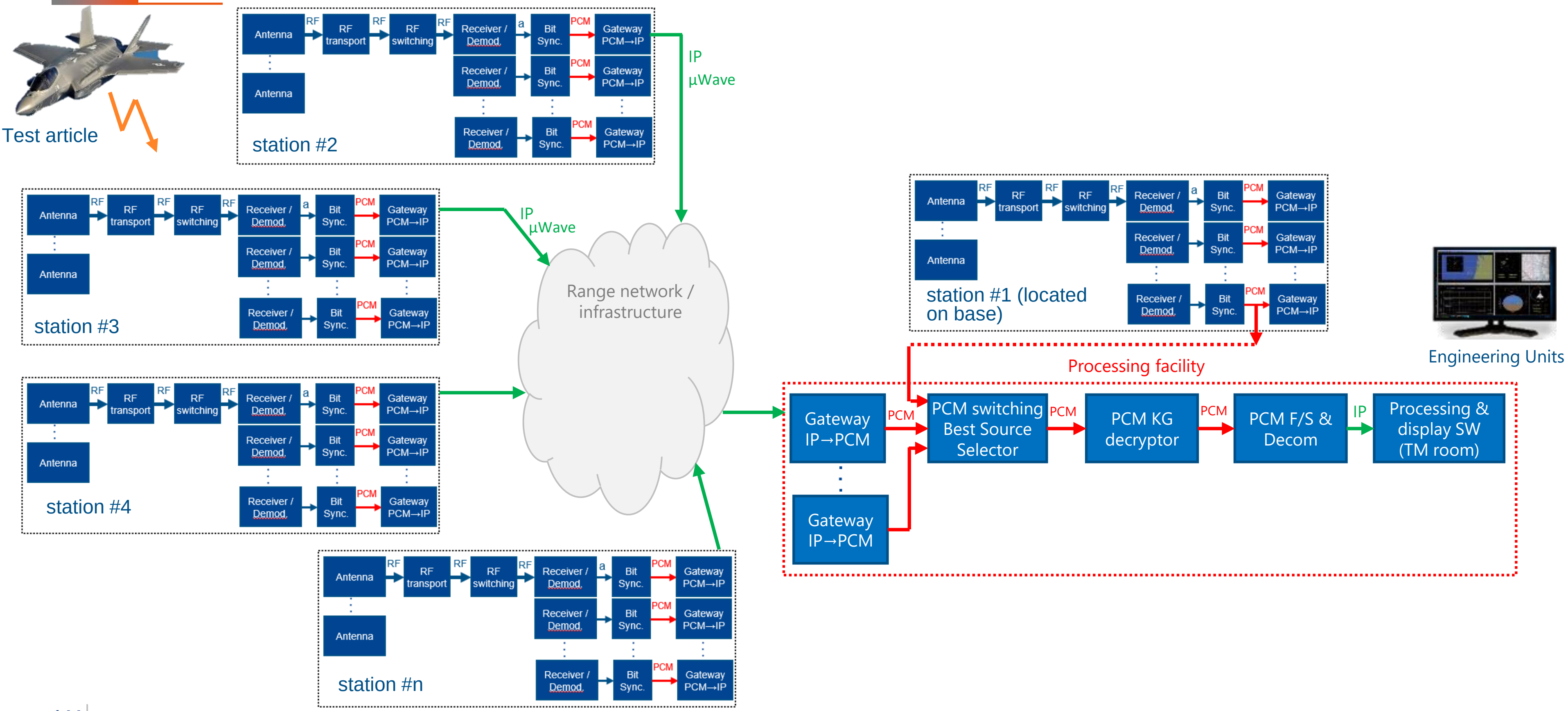
DoD range TM architecture : functional block diagram

- **Simplified architecture**
  - > One standalone TM station co-located with the processing facility
    - Direct PCM connection between receiver and the processing system
  - > Not encrypted TM link
    - PCM KG decryptor is not required



Overall functional view with multiple TM stations –

one test article with one TM signal



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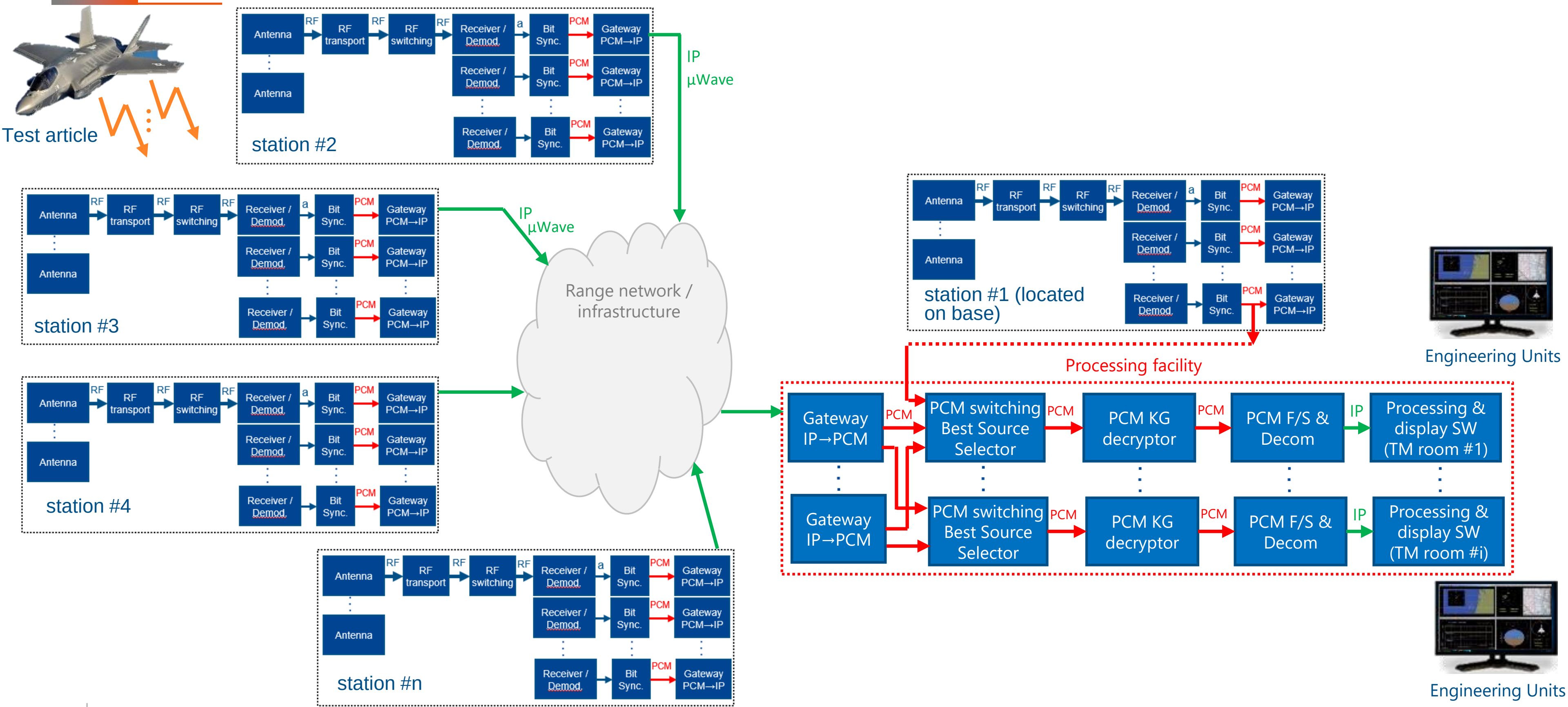
Overall functional view with multiple TM stations –

one test article with more than one TM signal



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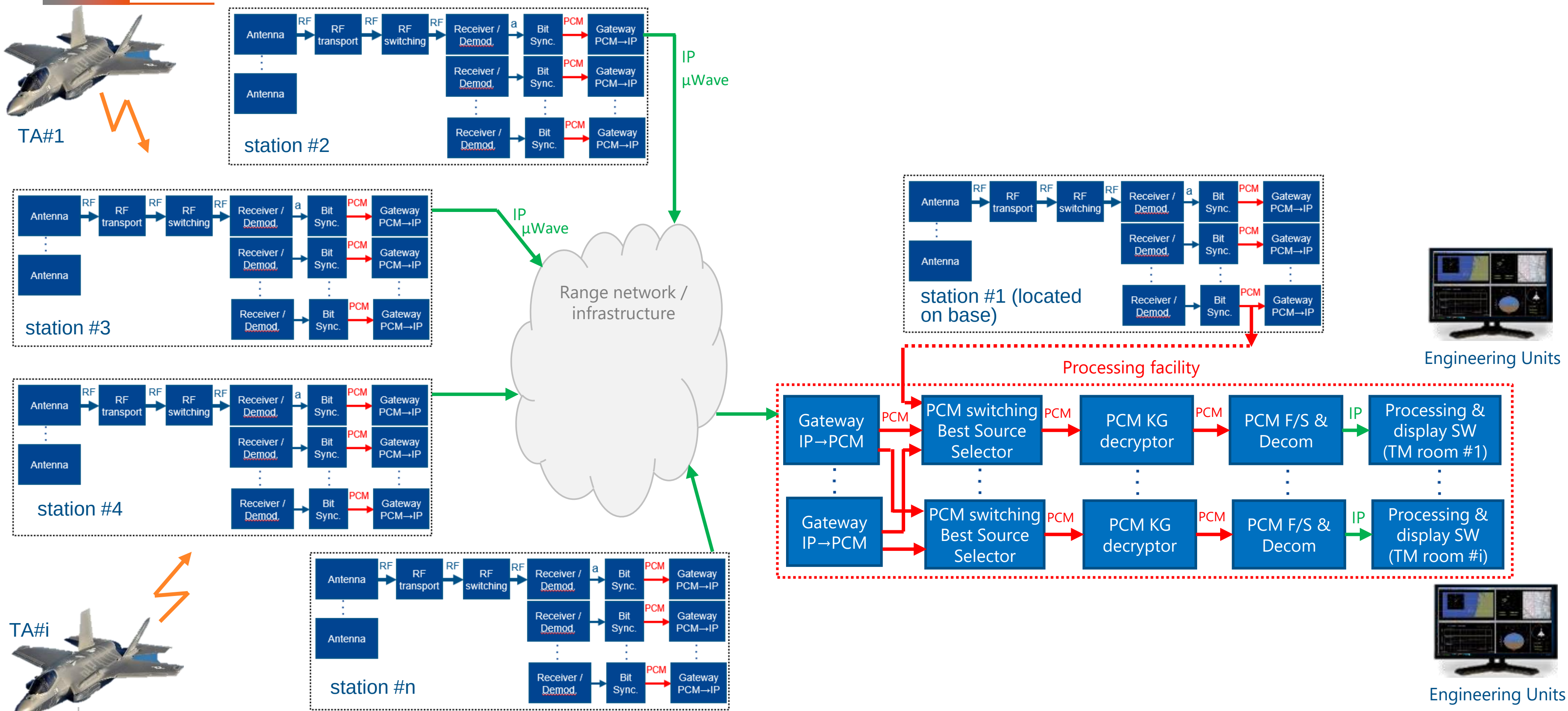
Overall functional view with multiple TM stations –

two test articles with one TM signal



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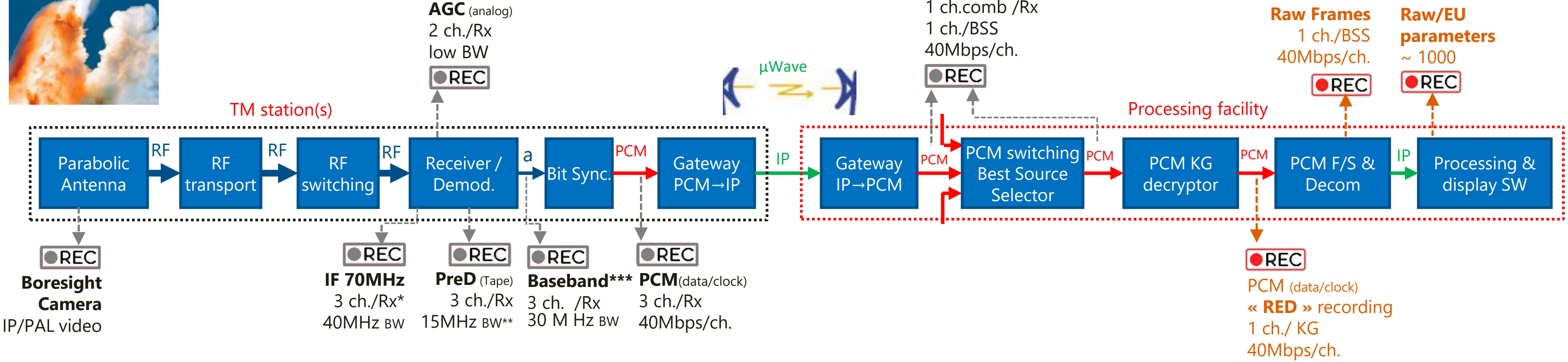
Recording in the functional block diagram (legacy) - Missile

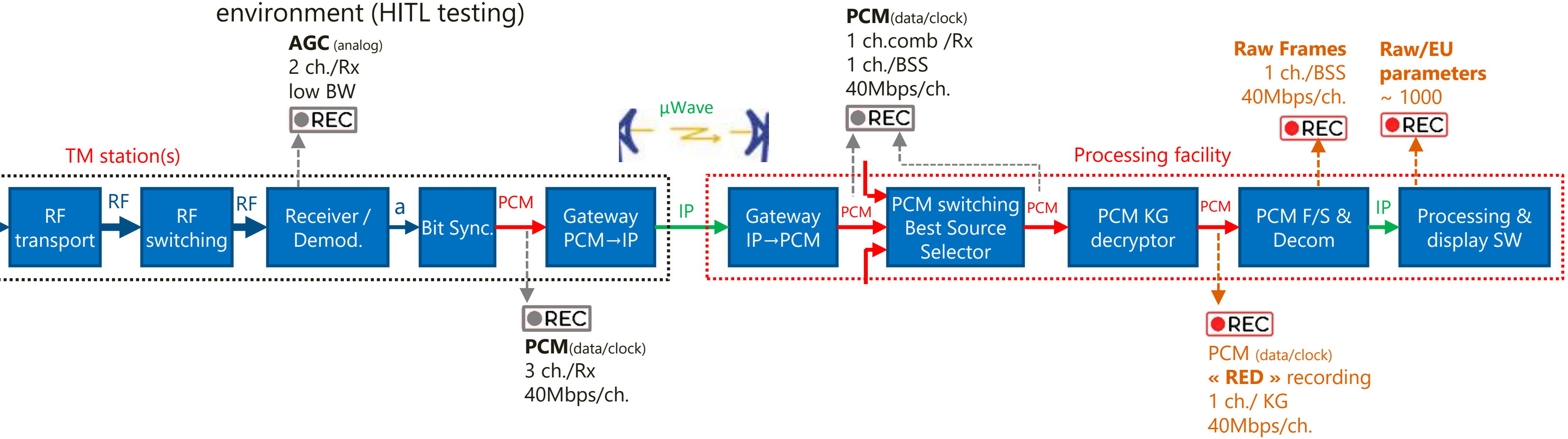
- **Where ?**
  - At all possible levels to secure the Telemetry collection
    - True for missions with no onboard recording and no platform recovery (missile, rocket,…)



** example is based on 1 antenna & 1 dual ch. receiver*
*** assuming 10MHz carrier and 2/3 BW rule*
**** baseband recording possible for analog waveform (ie PCM-FM)*

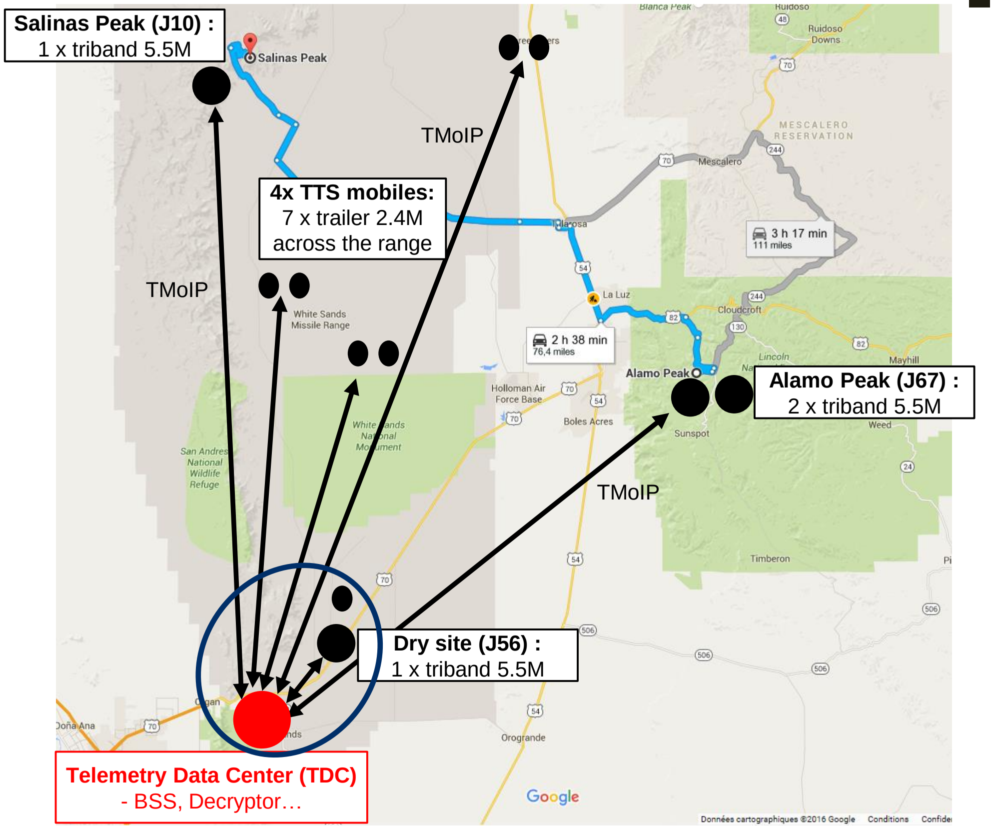
Recording in the functional block diagram (legacy) - airframe

- **Where ?**
  - Only at one or few levels as a backup to onboard recording
    - True for flight test of platforms being recovered or manned
    - Ground recording only used if glitch in onboard recording
      - Ground recording used as well to validate & qualify TM stations after mod. / upgrade (without having to fly)
      - Reproducing of real mission signals (ideally analog RF/IF level) stresses the stations with mission-like environment (HITL testing)



** example is based on 1 antenna & 1 dual ch. receiver*
*** assuming 10MHz carrier and 2/3 BW rule*
**** baseband recording possible for analog waveform (ie PCM-FM)*

WSMR range (US Army)



Overview

- 7 receiving stations (3 fixed / 4 mobile)
  - Each made of 1x tracking antenna and 12x dual ch. receivers
  - Receiver output is PCM (data + clock)
  - PCM recording on standalone recorder
  - All stations equipped with PCM->IP gateway boxes
  - Telemetry link can be encrypted or non-encrypted
  - Stations still manned but moving to fully remote M&C
- TDC : Telemetry Data Center
  - All remote station streams get centralized at the TDC building via WSMR range network
  - IP ->PCM gateway boxes to reconstruct PCM data/clock
  - Decryptors (KJ)
  - Best Source Selector(s)
    - PCM input / output Best Source Selector
    - need to support 84 channels (12 groups of 7 sources – assuming only combined channel per station)
  - Max bit rate to support : 30Mbps
  - WSMR design allows reception of up to 12 telemetry signals at the same time
    - 12 separate carrier frequencies hence 12 groups at the BSS

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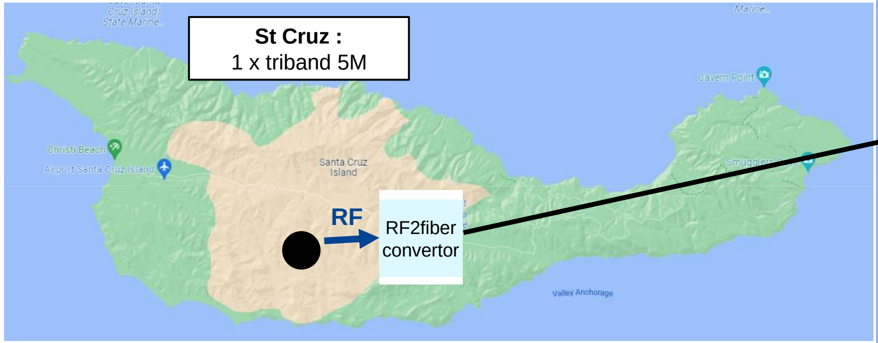
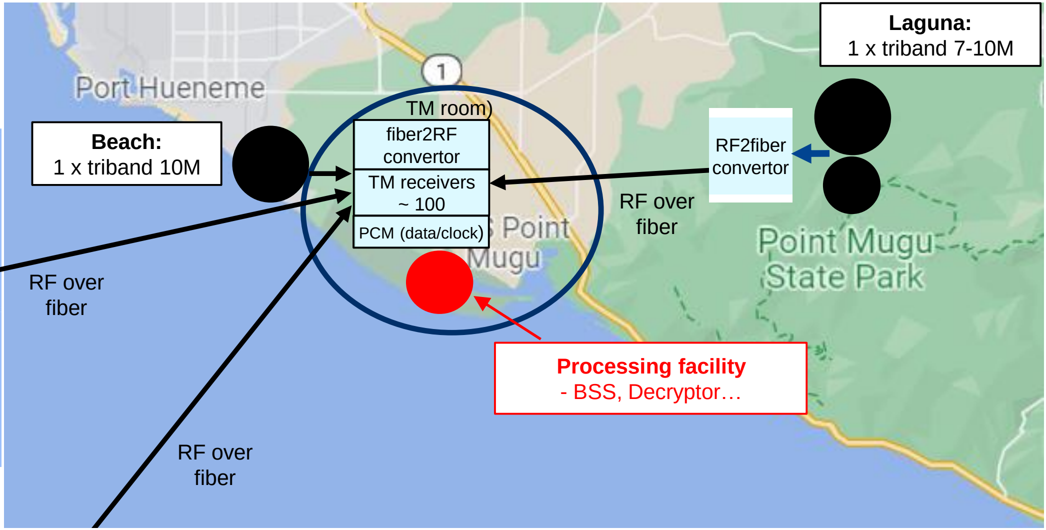
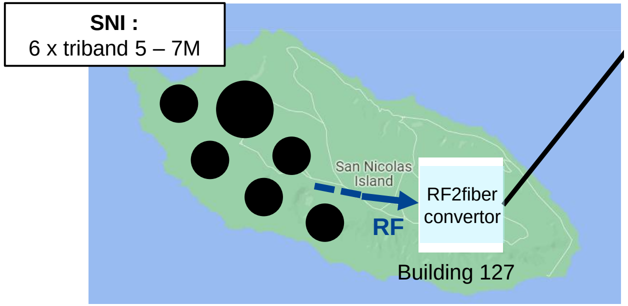
Point Mugu PMS Range (Navair)







Overview

- 4 main receiving stations
  - Each made of 1 to few tracking antenna – 5 to 10M
  - NO TM receivers at each station (only Auto-Track Rx), No recording
  - RF transported to Pt Mugu base via fiber
- NAVAIR base
  - Single room with all TM receivers (~100+)
  - Recording at baseband and PCM levels
  - PCM (data/clock) sent to Processing facility
- Processing facility
  - Decryptors (KJ)
  - Best Source Selector(s)

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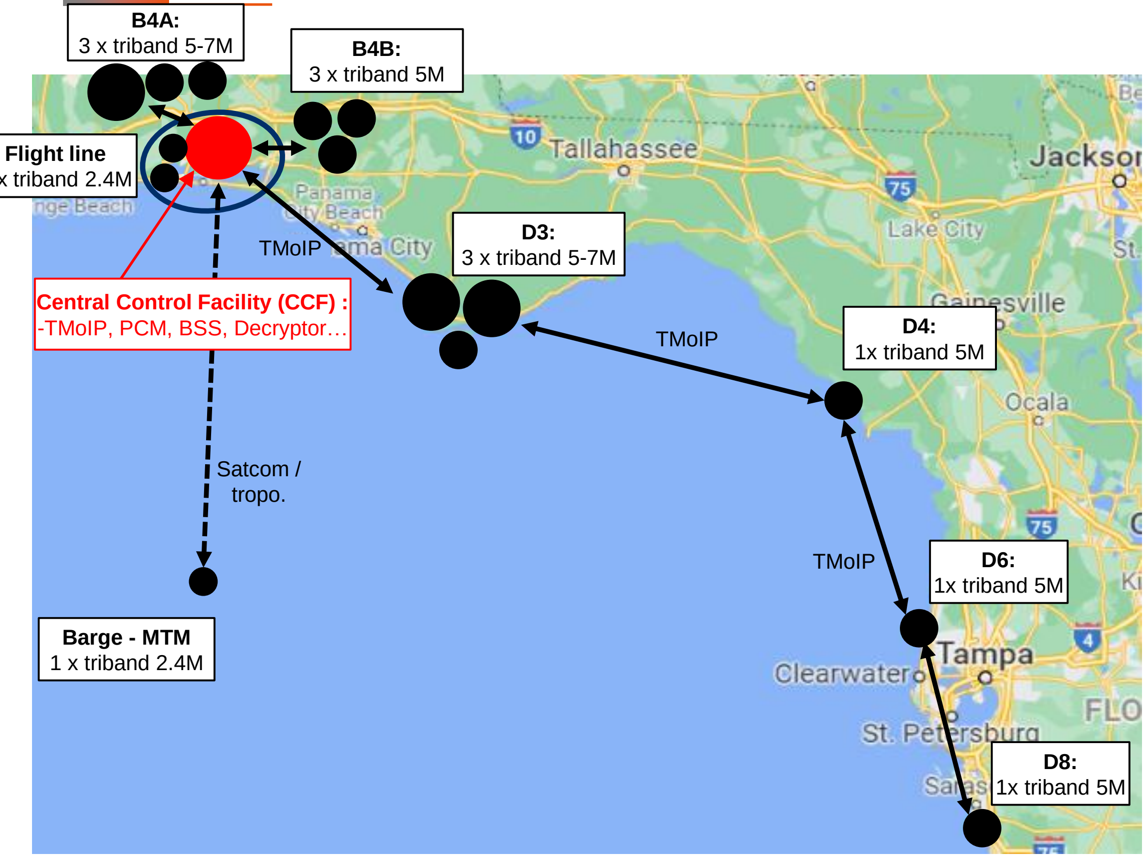
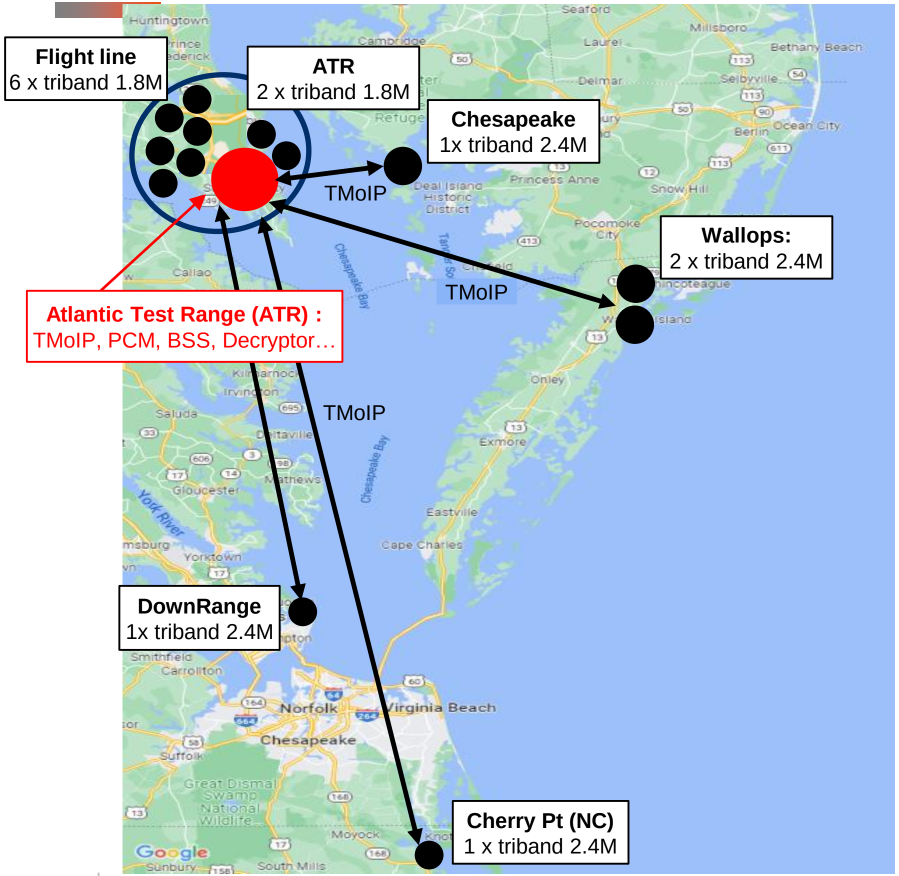
Eglin range (USAF)



Overview

- ~10 receiving stations
  - Each made of 1 to 3 tracking antennas – 5 to 7M, couple 1.8M/2.4
  - 8 dual ch. receivers per antenna (incl. auto-track)
  - PCM+**DQM** output from Rx to PCM->IP gateway boxes ("pseudo-wire" RCC218-P)
  - Recording of PCM data/clock
- Eglin AFB CCF
  - All streams centralized at "CCF"
  - PCM is reconstructed in Data/Clock with IP->PCM gateway boxes
  - Ch10 files recorded at each (remote) receiving station are transferred to the processing facility during the night for local archiving.
  - Start using BSS with PCM inputs (8 inputs w/t DQM; 8 output w/o DQM + 1 BSS)
  - 4 groups per BSS (2 or 3 sources per group)
  - Bit rate : 35Mbps / stream
  - Decryptors (KJ)
  - Recording of PCM data after decryptor.

PaxRiver range (Navair)



Overview

- ~10 receiving stations
  - Each made of 1 to 6 tracking antenna – 1.2 to 3M max, mainly 1.8M/2.4
  - 8 dual ch. receivers per antenna (incl. auto-track)
  - I&Q analog output into standalone BS to perform Type 2 Quality encapsulation (ie x1.4 bit rate expansion on ground)
  - Use of external PCM->IP gateway boxes. (use of “pseudo-wire” protocol RCC218-10/P)
  - Recording of PCM data/clock only after BS (ie w/t Type 2 DQE)
  - 2 airborne TM station (Airtec and PT-67 A/C) with C-band reRad.
- Atlantic Test Range (ATR) processing facility
  - 13 TM rooms all virtualized (can be reconfigured in 30mn)
  - All streams centralized at “ATR”
  - PCM is reconstructed in Data/Clock (IP->PCM gateway boxes)
  - 8 ch. PCM BSS (Type 2 DQE and moving to IRIG DEQ)
  - Typical use is one BSS per room (so per mission) with 2 groups of 4 sources (1 for the A/C and 1 for the captive missile)
  - Bit rate : 30Mbps / stream
  - Decryptors (KJ)
  - Recording of PCM data/clock after BBS (encrypted) and also after decryptor (clear/Red)

Best Source Selection Overview and IRIG Standard

Why using a BSS in a range ?

- Deployment of multiple receiving sites to support ranges extension
  - Visibility of test article is limited by the altitude of the flight / mission
  - Multiple antennas means coverage of a wider area

- Multiple antennas to offer different look angles
  - Prevent masking, onboard radiation nulls depending on test article maneuver

- BSS is (primarily) for Realtime
  - Program staff in TM room expect to receive the best possible TM while mission occurs

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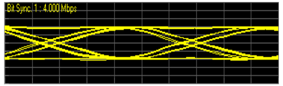
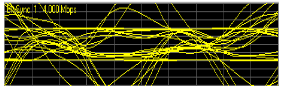
Which criteria used for source selection?

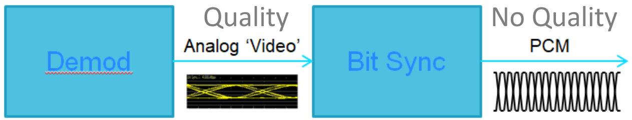
- **Use Signal Quality for any given source**
  - Quality is contained in the "analog" baseband signal (**Eye Pattern**) but lost on PCM stream after Bit Sync.
  - Good eye opening = **good quality**

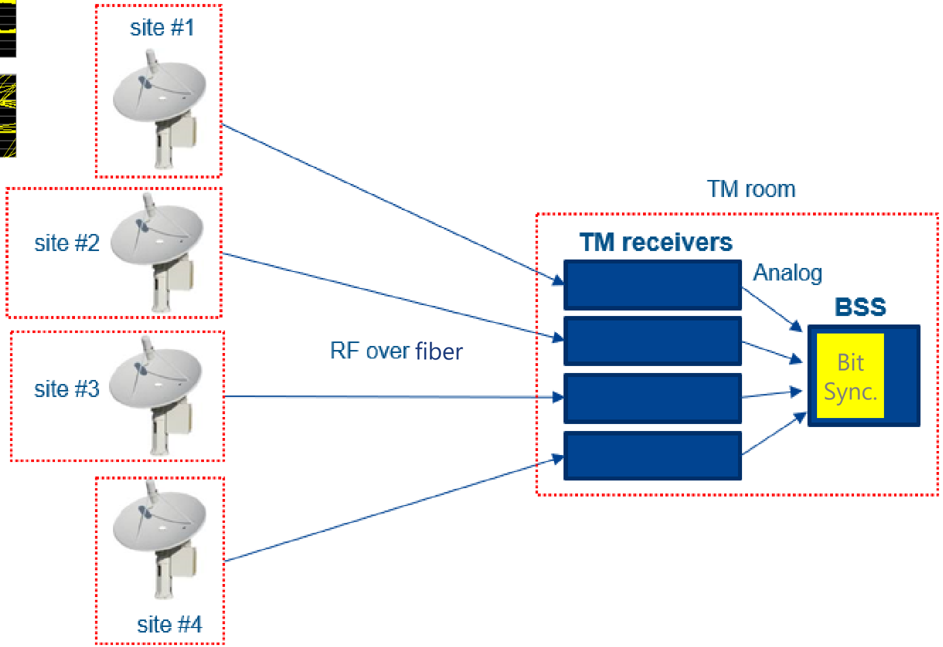


  - Limited opening = **poor quality**



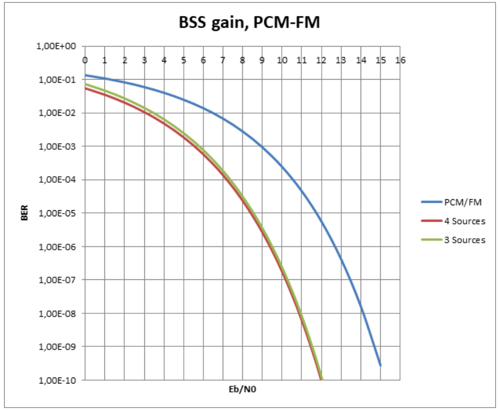
  - Possible to transport analog baseband signal over long distance **but not easy**
- **Case 1 : analog signals @ BSS**
  - All receivers collocated in same TM room
  - BSS derives signal quality from each source Eye Pattern using built-in bit sync. and then performs Best Source Selection
  - Source time realignment complicated
  - **Works for PCM-FM waveforms** but not optimized for more advanced waveforms (SOQPSK, LDPC…)





Synchronized PCM interface

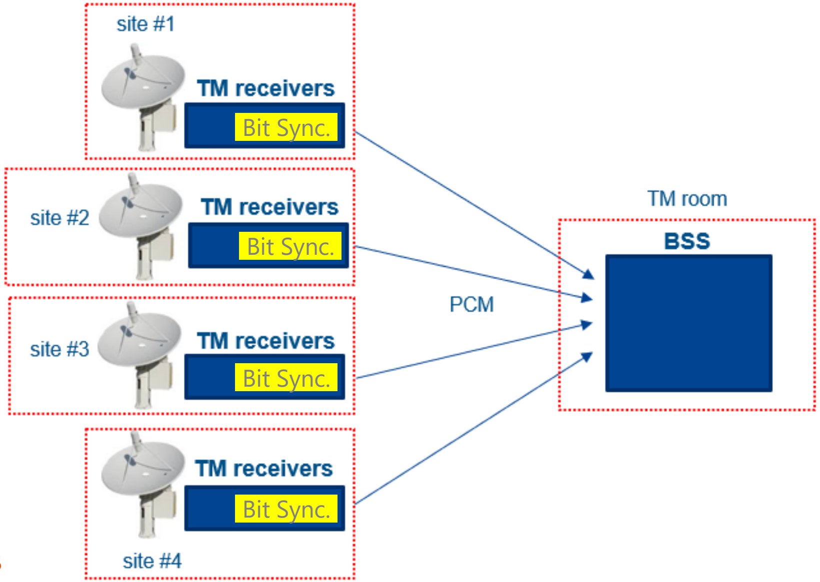
- **Case 2A : synchronized data (PCM) @ BSS**
  - Receivers are located at each receiving site
  - PCM output from TM receivers Built-in Bit Sync. (waveform agnostic)
  - PCM signal is easy to carry but **quality information is lost**. 2 selection criteria's available



Bit by bit majority vote gain

> **bit by bit Majority** vote
- **Typical 3.3dB** of source combining gain

> **Frame Synchronizer lock status**
- Less accurate information
- Does not work **on encrypted telemetry** (unless all incoming TM streams are decrypted pre-BSS)



> Need to carry the **quality information** together with the PCM stream
- DQM/DQE

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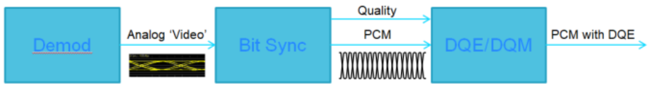
IRIG106 Data Quality Metric

- **Case 2B : synchronized PCM with quality @ BSS**
  - Receivers at each receiving site derive the quality info and insert it into the PCM stream using **IRIG106 DQE/DQM**

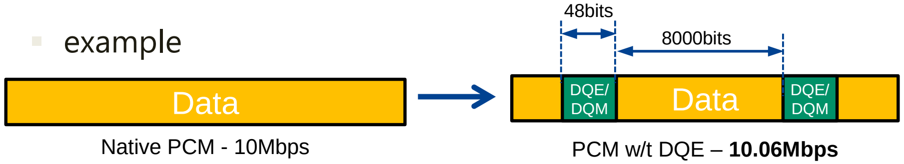


  - Data Quality Encapsulation / Data Quality Metrics
  - DQE header inserted within the data payload at regular interval → slight bitrate increase

16 Bits	12 Bits	4 Bits	16 Bits	1024 – 16384 Bits
SW	RSV	VER	DQM	PAYLOAD

    - DQM = 16 bits within the 48bit DQE header
    - DQM ranging from 0 (very poor quality) to 10 (best quality)
    - Data payload intervals = 1024 to 16K (default 4096 bits)

  - example



  - DQE/DQM stripped out at the BSS output

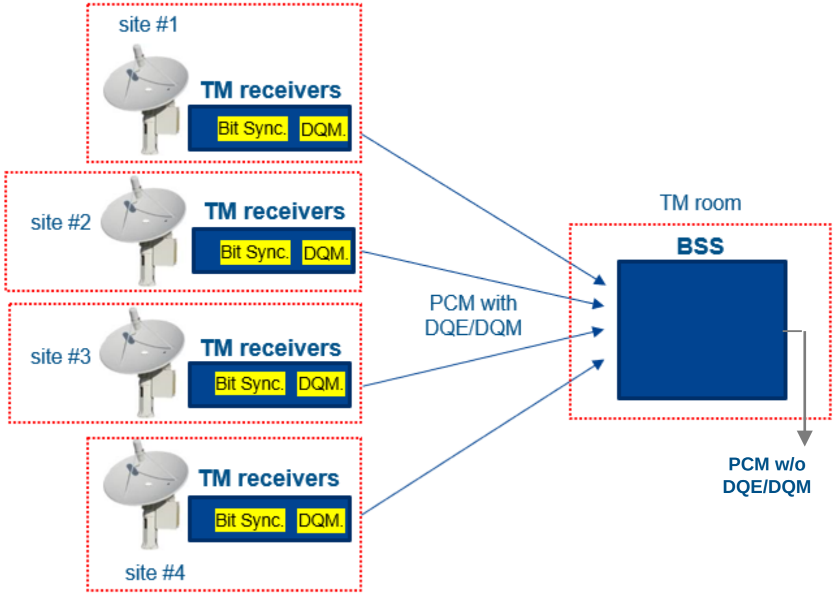
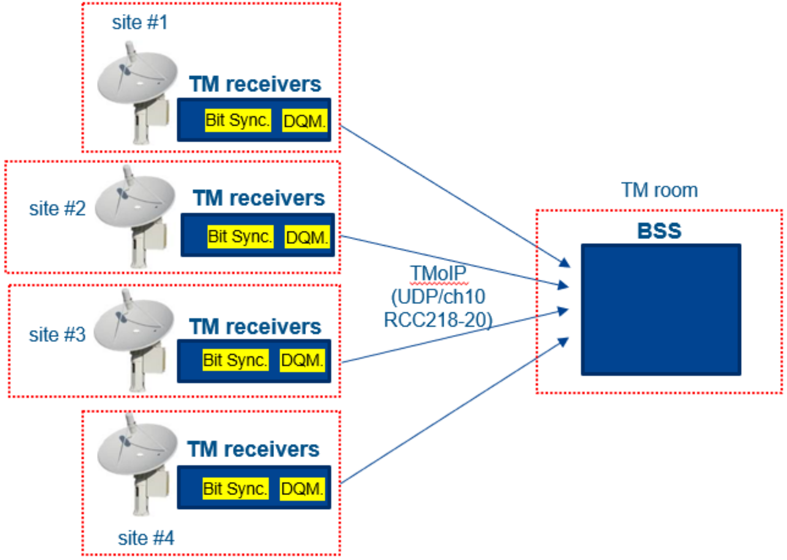


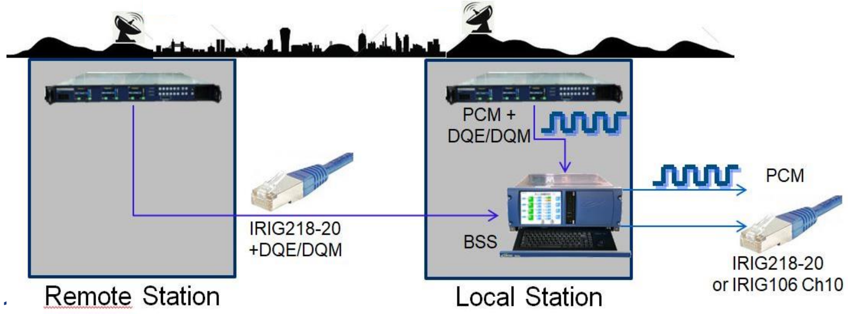
Table G-1. BEP Verses DQM

BEP	LR	DQM	Q
0.5	1.00	0	0
1e–01	1.11111e–01	5211	1
1e–02	1.01010e–02	10899	2
1e–03	1.00100e–03	16382	3
1e–04	1.00010e–04	21845	4
1e–05	1.00001e–05	27307	5
1e–06	1.00000e–06	32768	6
1e–07	1.00000e–07	38229	7
1e–08	1.00000e–08	43691	8
1e–09	1.00000e–09	49152	9
1e–10	1.00000e–10	54613	10
1e–11	1.00000e–11	60075	11
1e–12	1.00000e–12	65535	12

Native TMoIP and hybrid use

- TeleMetry over IP (TMoIP) capability
  - BSS directly process TMoIP stream in UDP/ch10 and IRIG218-20
  - no external TMoIP conversion boxes required
  - Use “DQE encoded / frame aligned” mode to properly transport the DQM along with the TM stream
  - Time tagging at the TMoIP emitters (receivers or TMoIP boxes) help the time alignment
  - Gbps-class aggregated bitrate
    - Virtually unlimited TM streams (Typ. 32x40 Mbps)
- Mix incoming signal type – Hybrid BSS
  - Can mix either physical PCM and TMoIP streams for a given group





Block / group definition

> 1 group of 16
> 2 groups of 8
> 4 groups of 4

> a BSS chassis embeds multiple BSS’s

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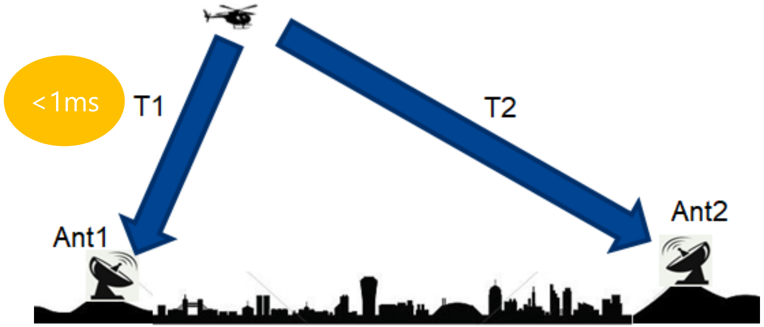
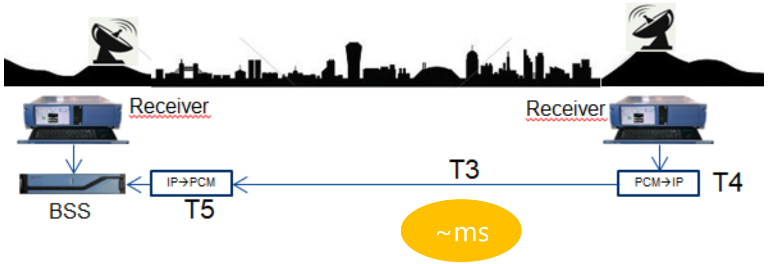
Time alignment

- Latency of each TM streams are different
  - Time between test article transmission and reception at the BSS
- Sum of a variable and fixed latencies
  - Variable latency depending on the position of the test article vs. the antennas (propagation time in the air T1 & T2)
  - Fixed latency related to the infrastructure (time through the network T3, latency in conversion devices T4 & T5)

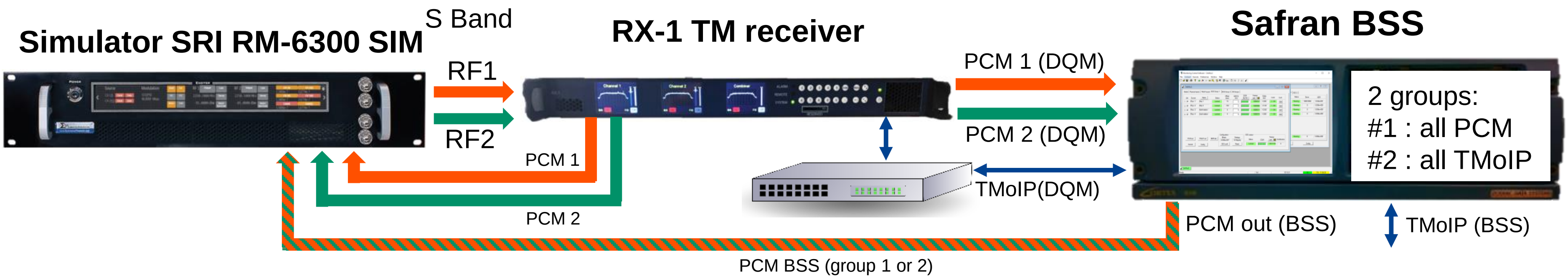




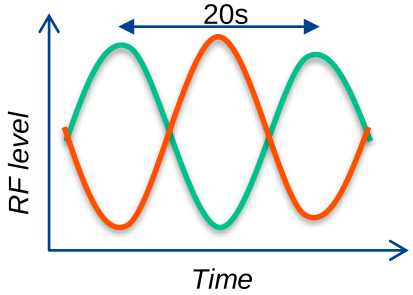
- The BSS needs to realign the streams to have seamless transition between them
  - 65kbits buffer for Dynamic / Variable alignment (65ms @ 1Mbps or 6.5ms @ 10Mbps time windows)
  - A static alignment of up to 1s configurable for fixed latency

Best Source Selector Demo

■ Dynamic selection using Data Quality Metric (DQM) over PCM and TMoIP

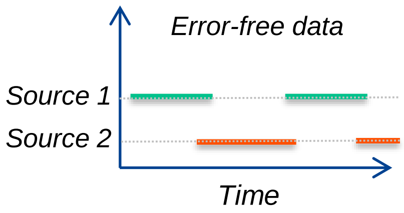


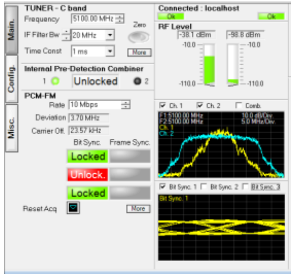
TM SIM w/ dynamic fading + BERT
2 sources 10 Mbps (Tier-0, 1 + LDPC)
BER, BEP/DQM



Demodulation + Quality estimation

- PCM (w/t DQM) output
- TMoIP (DQE encoded)
  - * IRIG218
  - * UDP/ch10 thru



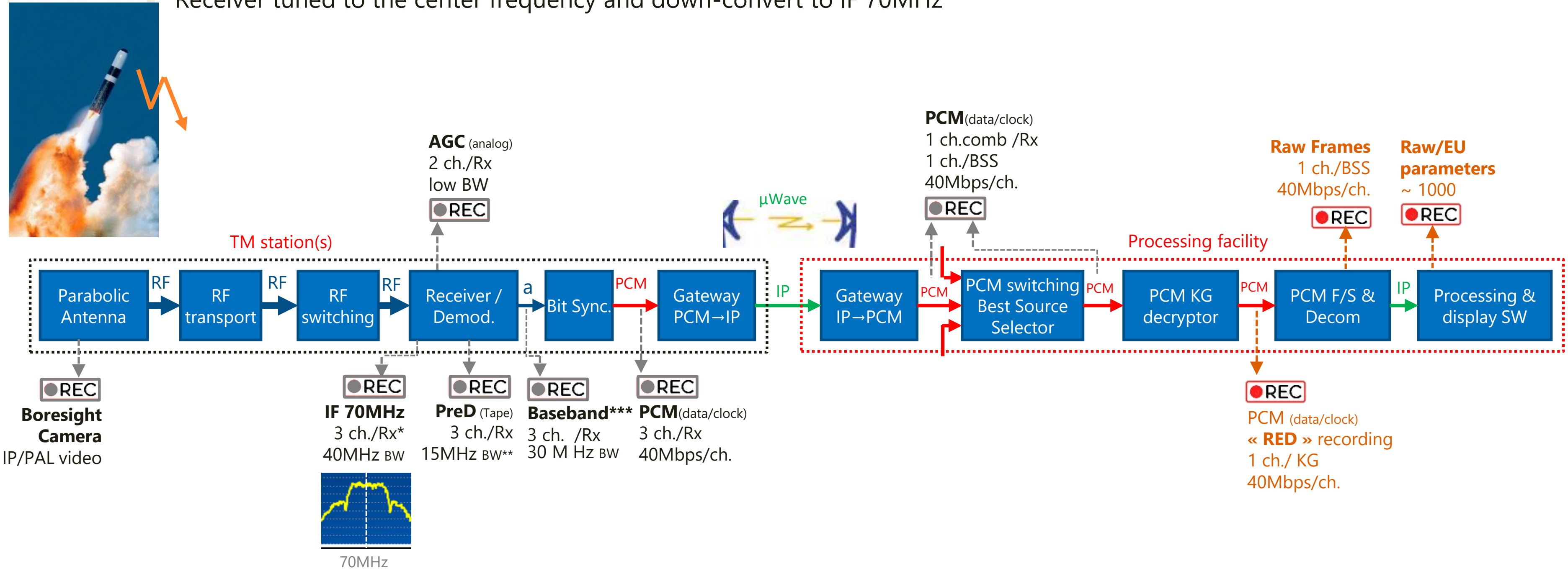


Data sampling w/ DQE + Realtime alignment & Source selection

Ultra-Wide Bandwidth RF recording

Recording in the functional block diagram (legacy)

- **IF 70MHz recording**
  - One TM signal per receiver
    - Receiver tuned to the center frequency and down-convert to IF 70MHz



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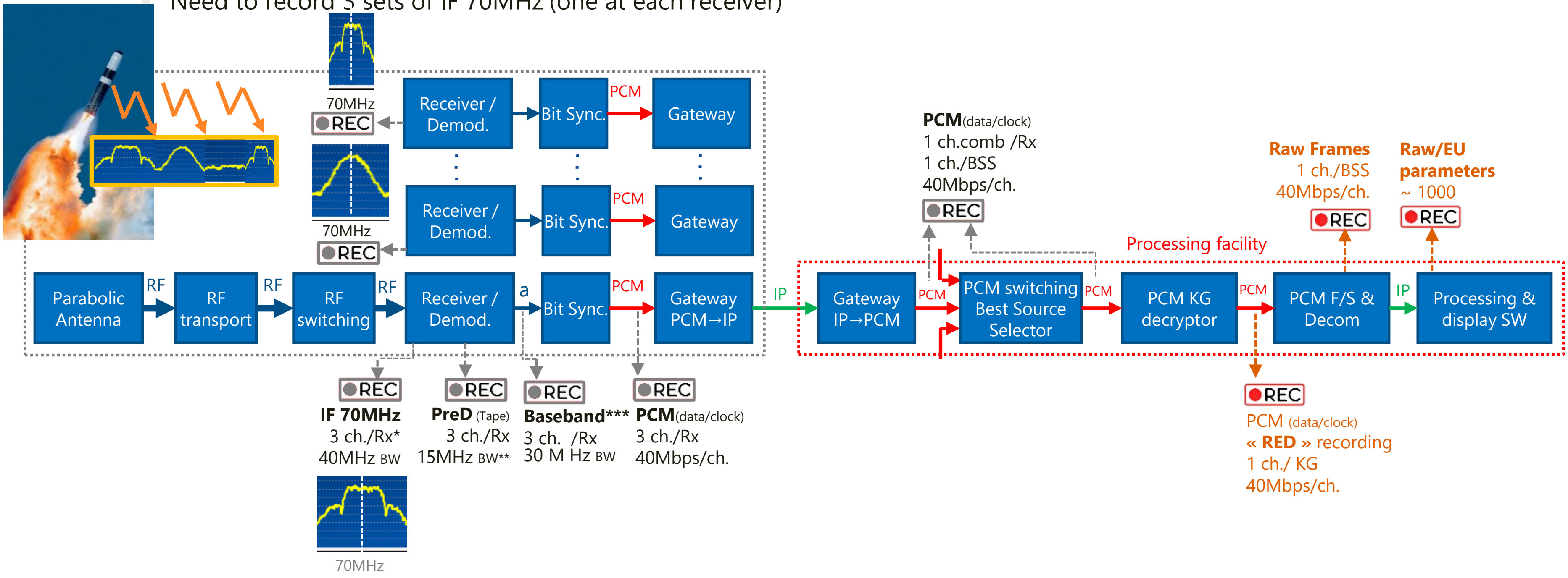
Recording in the functional block diagram (legacy)

- **IF 70MHz recording**
  - Assuming 3 S-band TM signals from a test article
    - Need to record 3 sets of IF 70MHz (one at each receiver)



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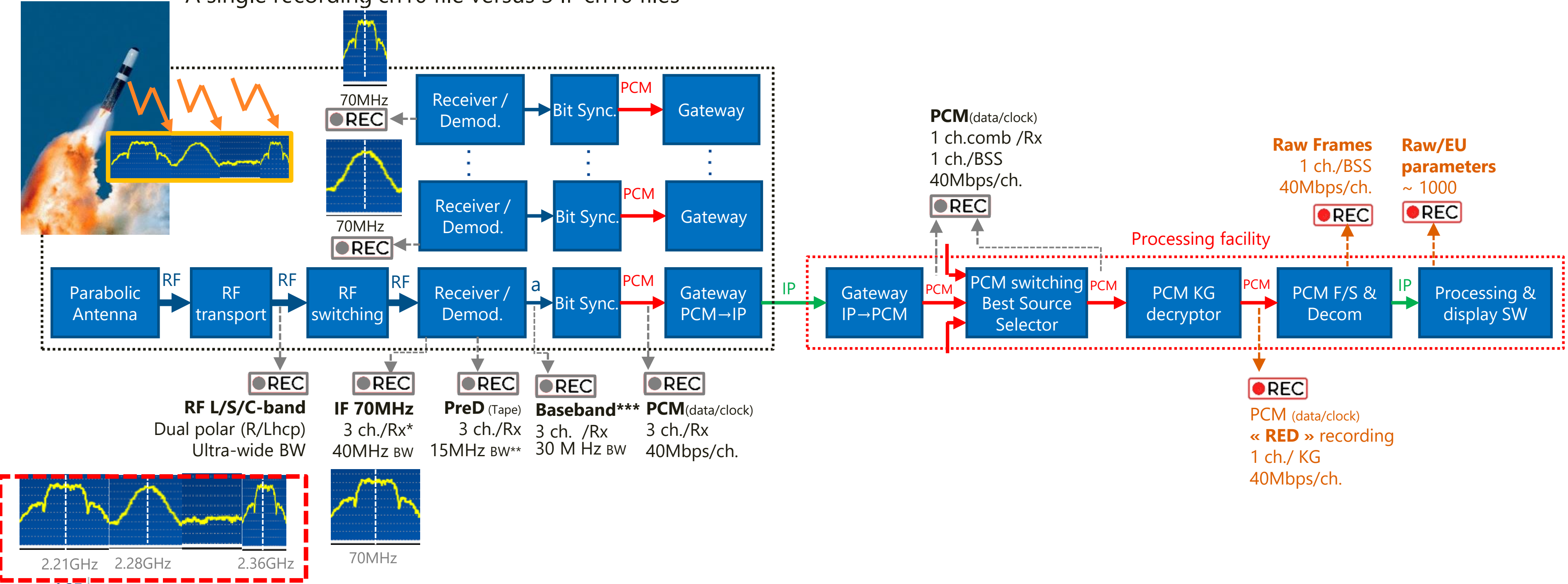
Recording in the functional block diagram

- **RF recording**
  - Record the S-band spectrum 2200 – 2400MHz with the 3 TM signals
    - A single recording ch10 file versus 3 IF ch10 files



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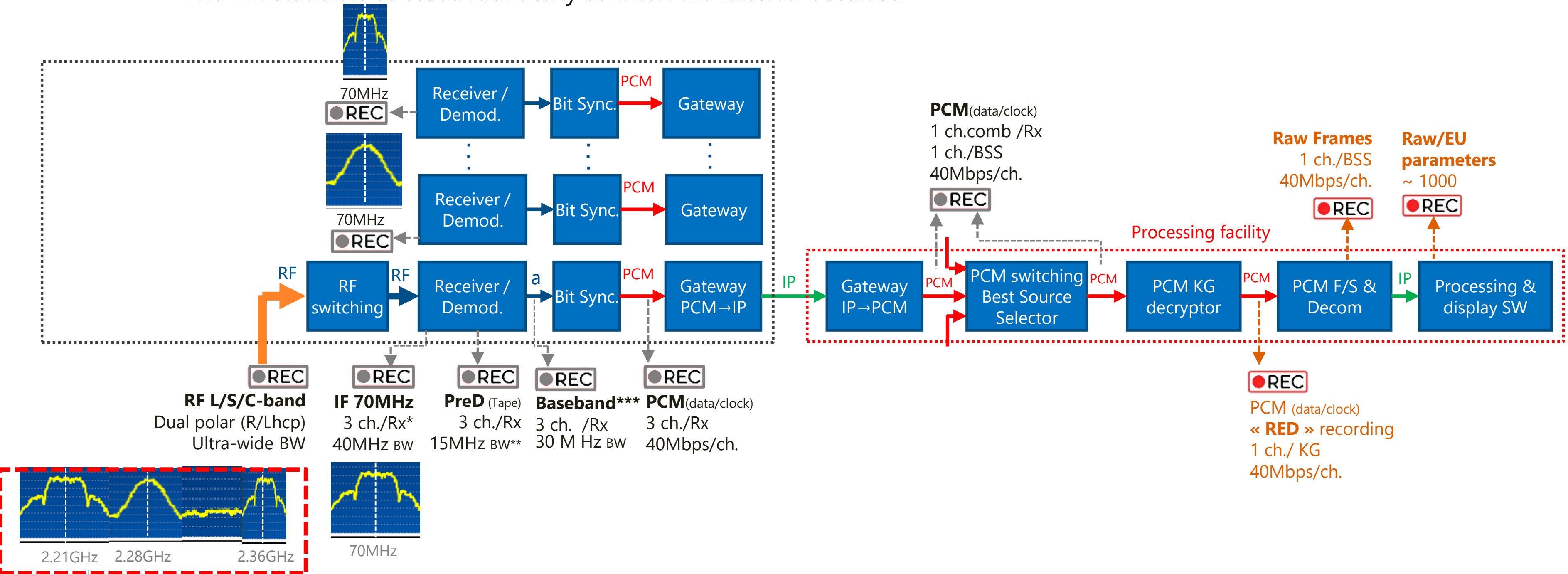
RF playback in the functional block diagram (legacy)

- **RF reproducing**
  - The same RF S-band spectrum 2200 – 2400MHz with the 3 TM signals reconstructed into the RF switching (multicoupler)
    - The TM station is stressed identically as when the mission occurred



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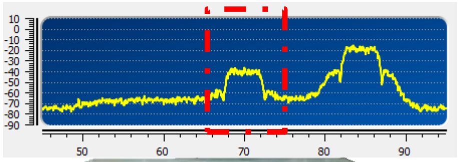
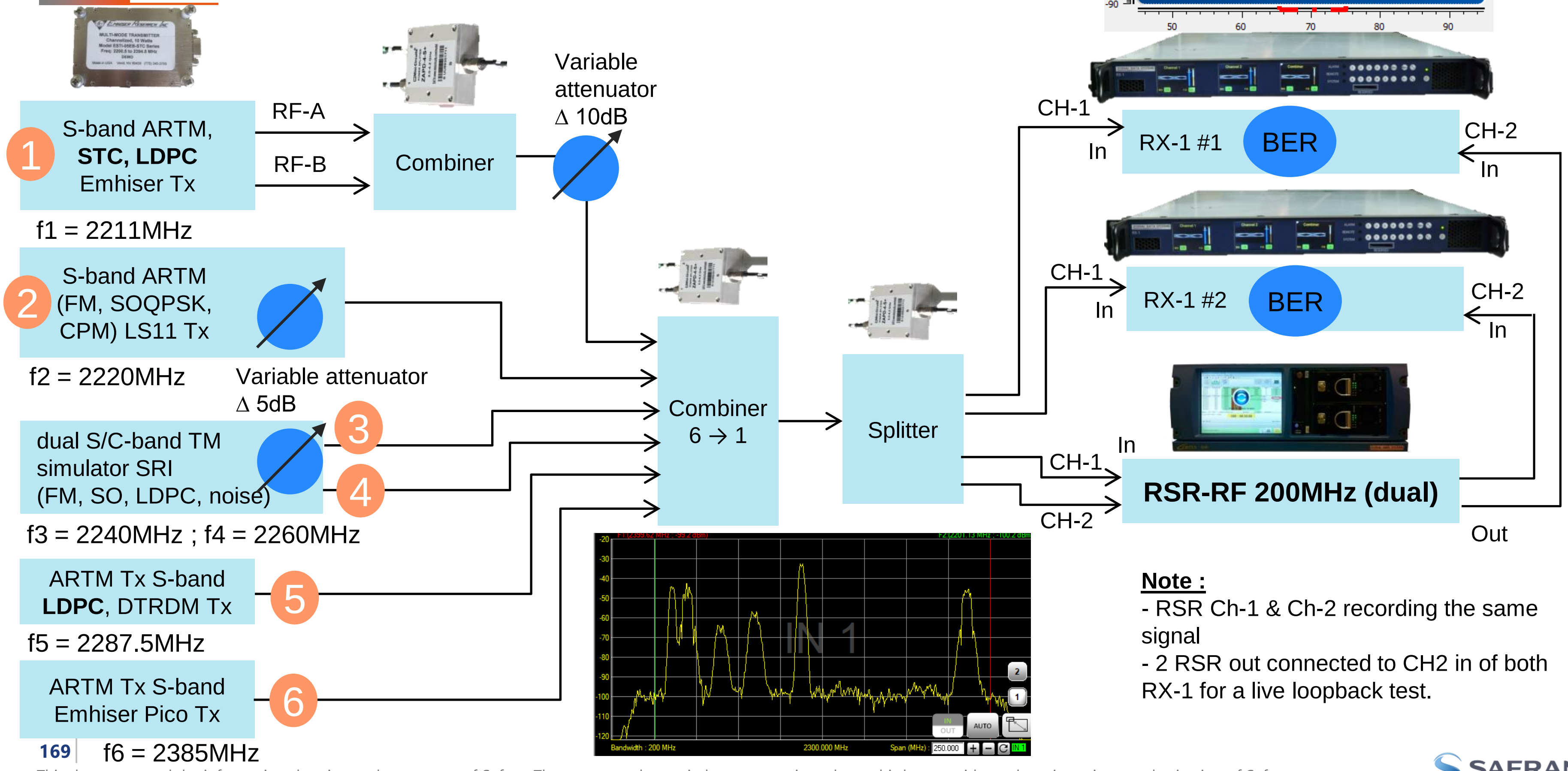
RF Recorder attributes

Area	Specifications	Proposal
Dual polarizations	Two RF inputs and outputs	Two N inputs Two N outputs
C band	[4400 5250] MHz	C-IF IRIG106 compliant embeded down-conversion
S band	[2200 2400] MHz	Direct digitization and synthesis
Time synchronization	nano-second class	Digital processing specification (FPGA)
Phase noise	Irig 106 compliant	Carrefull choice of components, and RF design
Dynamics	0 to -100 dBm	Multi-GSps, high dynamics ADC and DAC
	Noise figure < 10 dB	Carrefull choice of components, and RF design
Recording	Chapter 10, analog format 3	Digital processing specification (FPGA and SW)
Storage	15.4TB Extractible and reliable Capable of +10 Gbps R/W	High End NVMe storage unit
Bandwidth	Selectable, from 200 MHz (250 MHz) to 625 kHz (781 kHz)	Digital processing specification (FPGA)
Time Reference	Irig 106 reference, along with 1PPS Input and output	RSR inherited interfaces and processing
Frequency Reference	10 MHz input and output	RSR inherited interfaces and processing

Safran RSR-RF demo diagram (Rec + E2E)



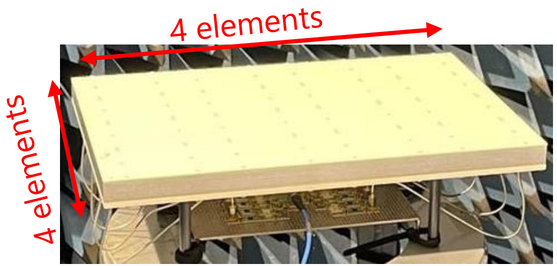


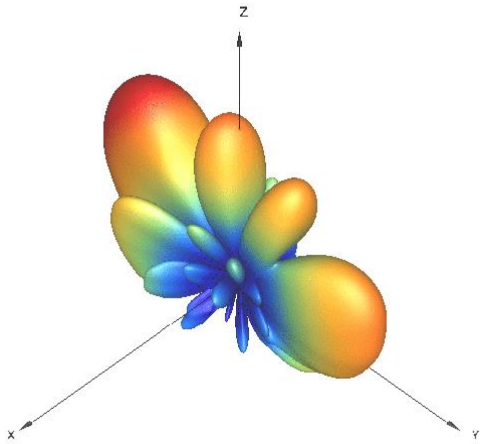
Note :
- RSR Ch-1 & Ch-2 recording the same signal
- 2 RSR out connected to CH2 in of both RX-1 for a live loopback test.

Phased-array antenna
Overview and use cases

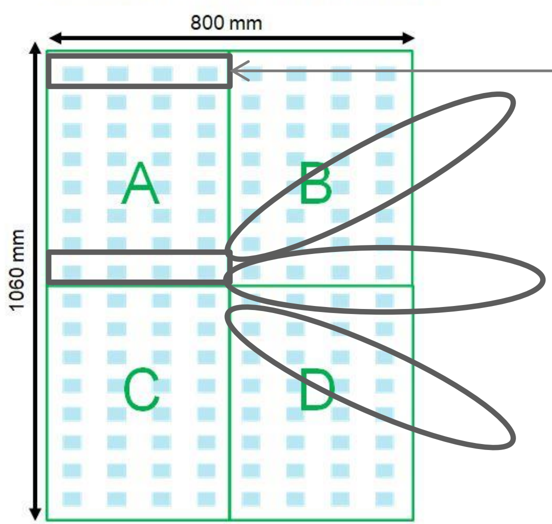
Active Electronically Scanned Array (AESA) antenna

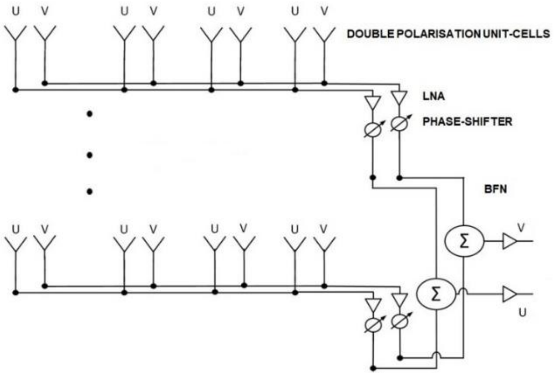
- **Concept**
  - Replace Mechanical pointing with Electronic pointing (or beamforming)
    - No more moving parts
  - An AESA antenna is a collection of sub-array panels with radiating elements
  - Shape of the beam constantly changing
    - Phase-shifter commands are dynamically updated





Cut-plane for theta - 45° to + 45°





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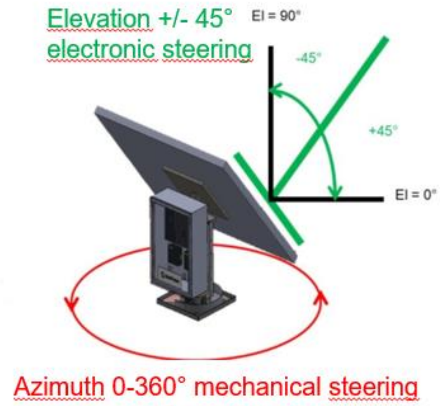
Active Electronically Scanned Array (AESA) antenna

Type

- Analog beamforming:
  - RF signal is not digitized and phase-shifter applied directly on Analog signal of each sub-array element
- Digital :
  - RF signal fully digitized for digital signal processing (channel tuning, regulation, ...)
- Could be an hybrid of both
  - i.e. mechanical pointing in Az. while electronic pointing in El. (as shown)

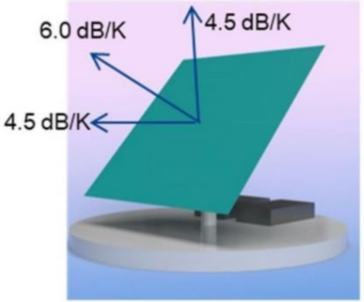


Differences

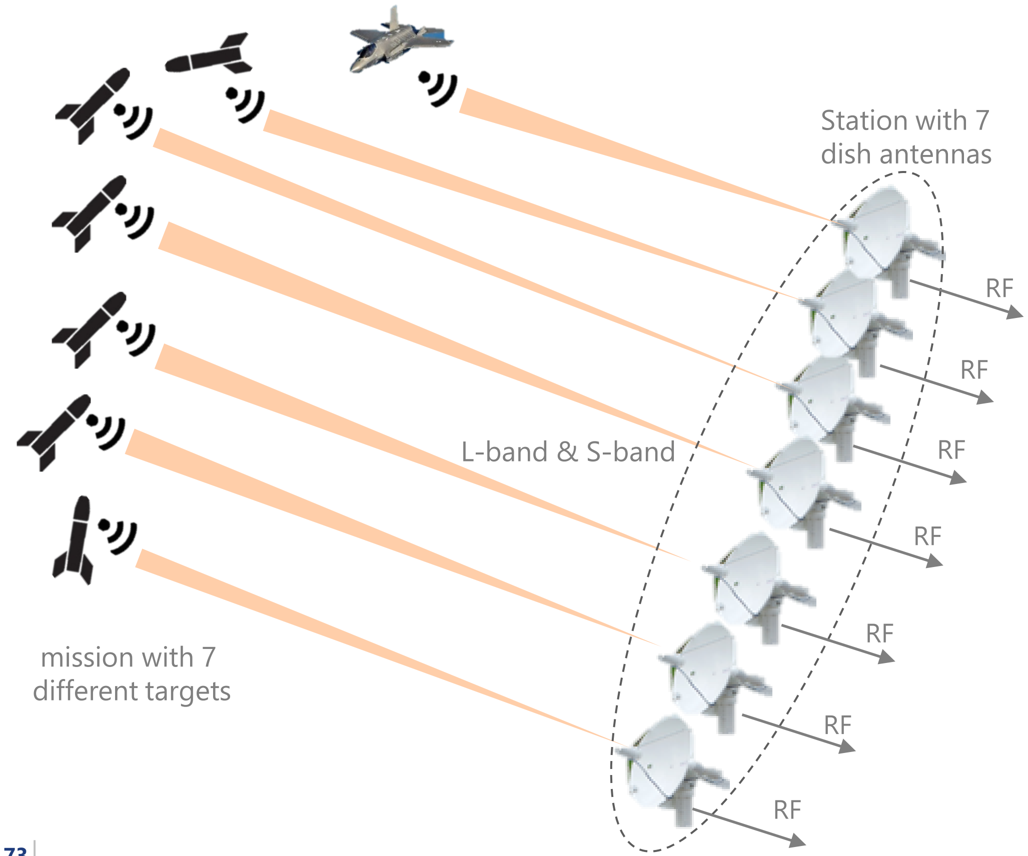
- Analog: Large BW at once (ie 200MHz vs 40MHz) ; RF signal dynamic range is preserved
- Digital: Pre-processing possible (AGC, preD combining); mitigate Multipaths; heat!

Characteristics

- How many simultaneous beams ?
  - Single one to more than 10 at once!
- Gain (G/T) linked to the array area. The wider array, the larger gain
  - Maximized at look angle perpendicular to the array
- RF band covered
  - Dual band L&S OK, but support of triband LSC requires 2 separate arrays
- Outputs
  - Single channel at fixed IF 70MHz or multiple channels in native wideband RF spectrum



Example of an AESA application



- **Mutliple targets (dish)**
  - Mission scenario with a large number of targets (here 7) being tracked from a given station
  - Rule with dish antennas is one target = one antenna
  - Lack of real-estate to install multiple dish tracking antennas
  - Associated maintenance, spares and reliability

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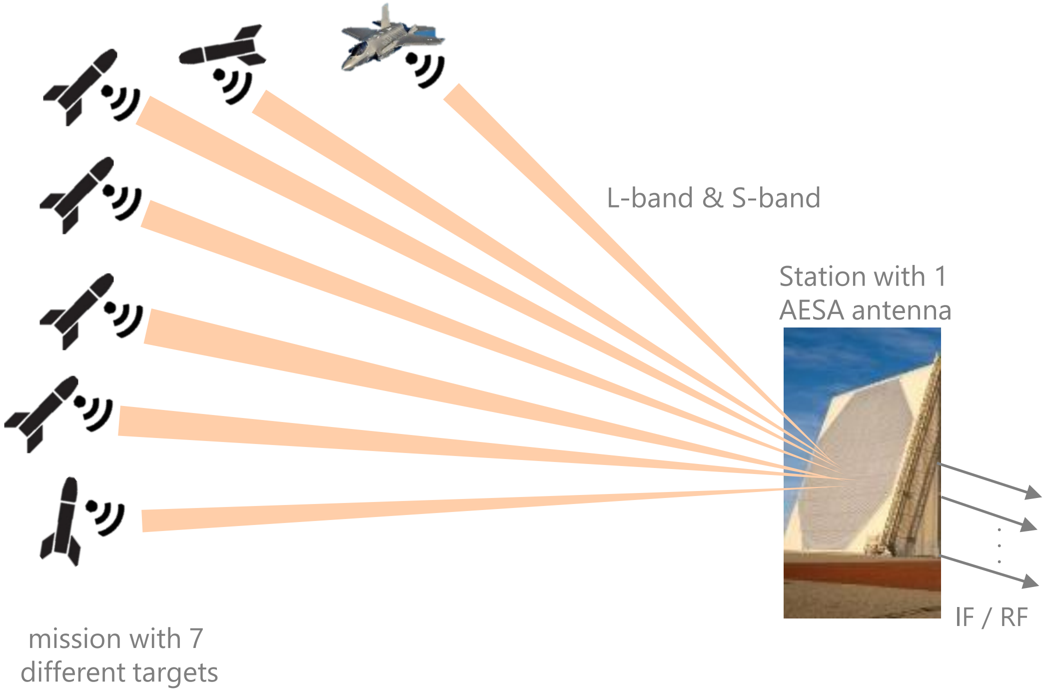
Example of an AESA application



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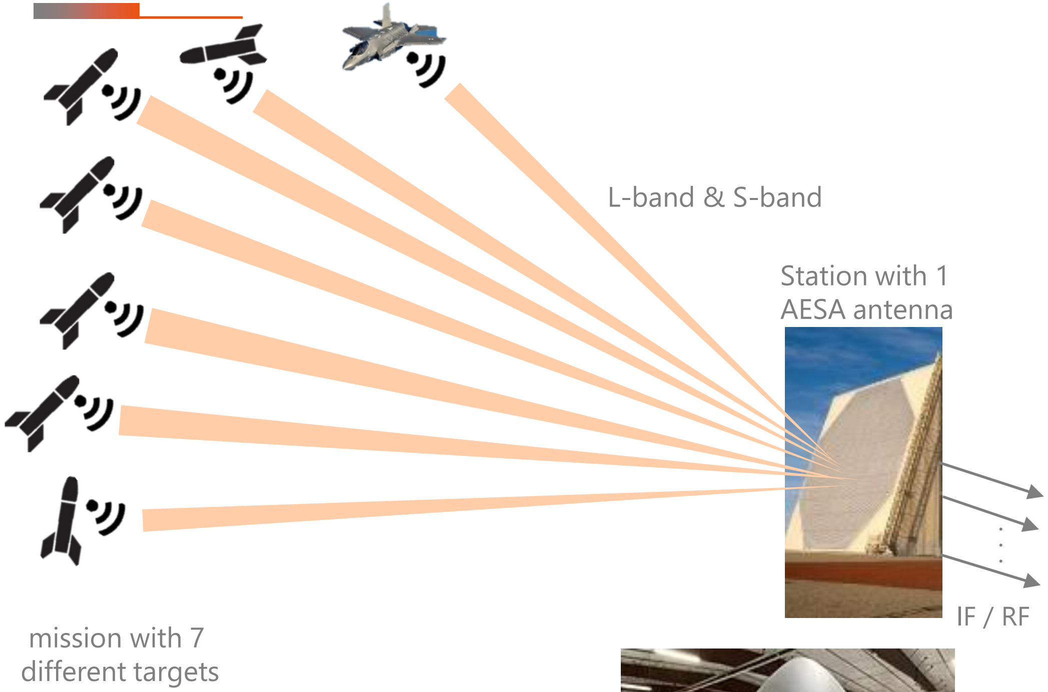
- **Mutliple targets (AESA)**
  - A single AESA antenna can replaced the 7 individual dishes
  - Outputs for each individual beam / channel depending on AESA technology
    - 200MHz RF in Analog (can contain multiple TM signals from the same target)
    - 40MHz IF 70MHz in Digital (frequency tuning performed so only one TM signal per output)

Example of an AESA application



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  - Outputs for each individual beam / channel depending on AESA technology
    - 200MHz RF in Analog (can contain multiple TM signals from the same target)
    - 40MHz IF 70MHz in Digital (frequency tuning performed so only one TM signal per output)
- **Airborne A/C**
  - Modular array shape makes it ideal for airborne TM station (ie Red-rad A/C)

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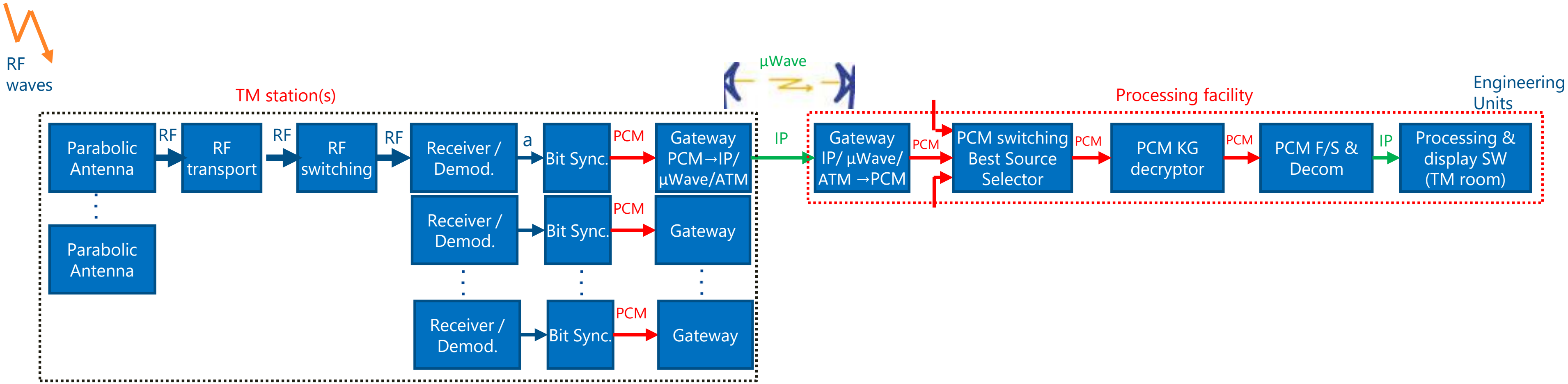
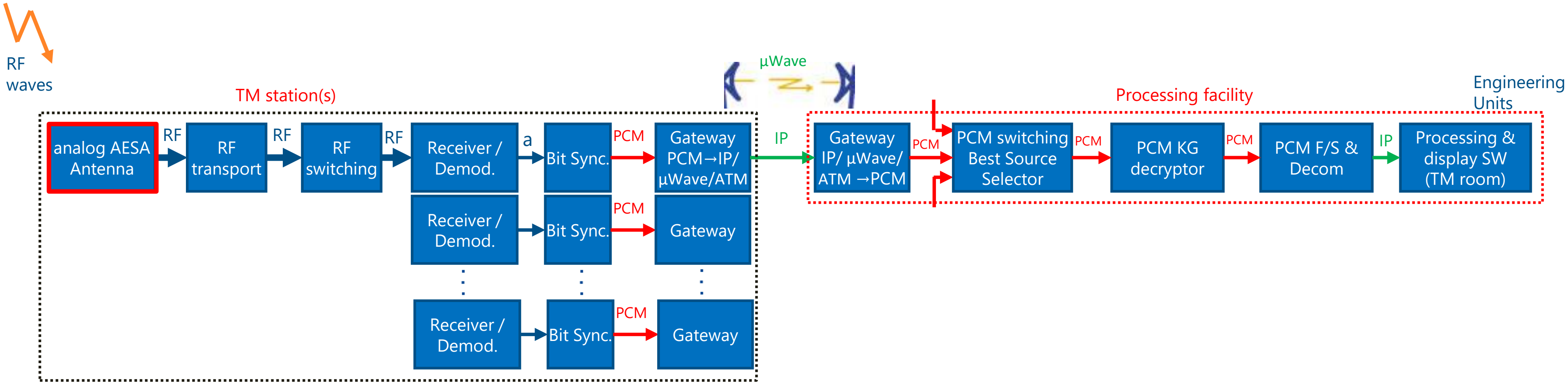
AESA Impact on the range TM architecture



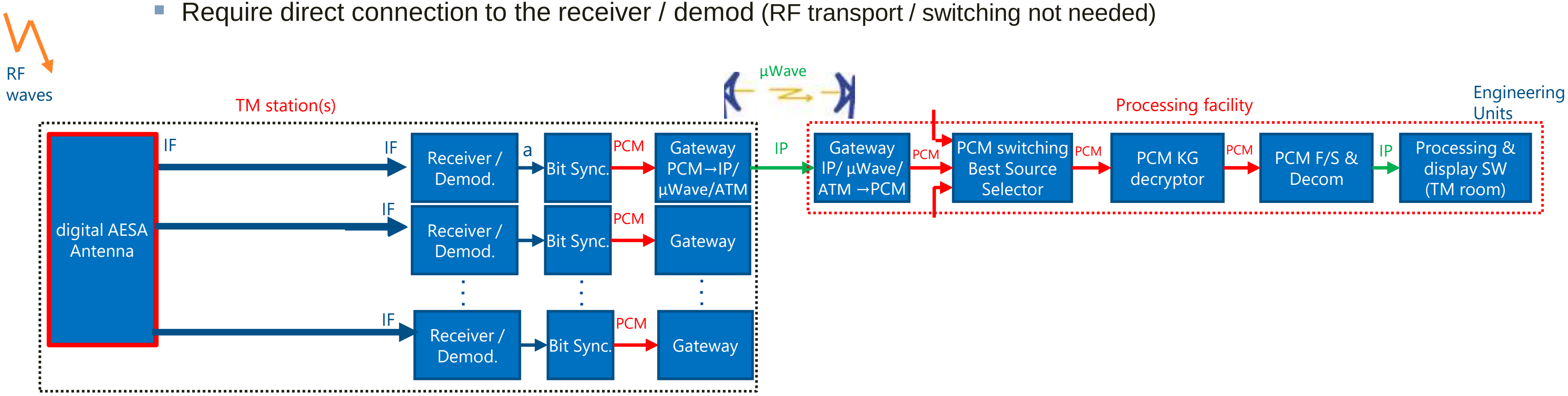
AESA Impact on the range TM architecture

- **Analog AESA**
  - > Several dish antennas simply replaced by one AESA antenna
    - Native RF outputs available like if it was a collection of dish antennas
  - Standard Telemetry sub-system architecture remains unchanged



AESA Impact on the range TM architecture

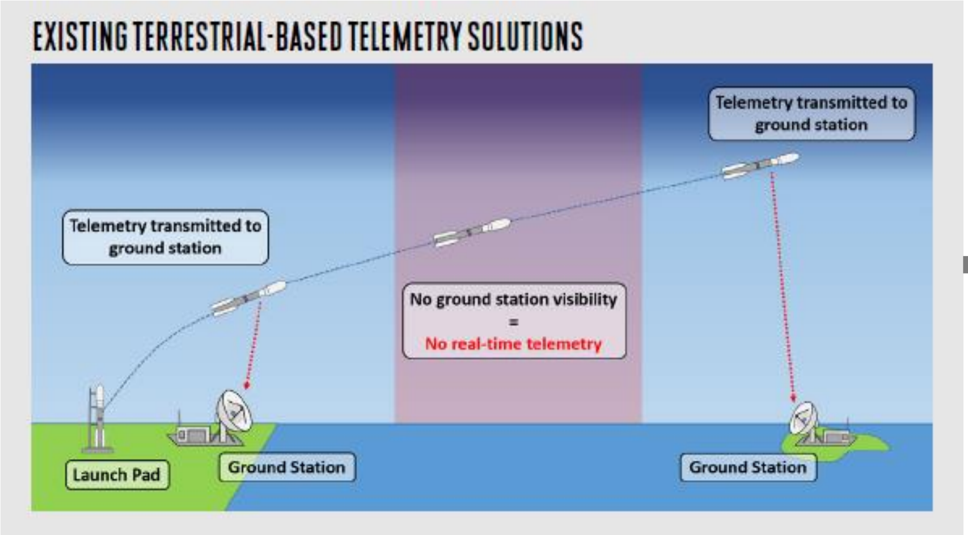
- **Digital AESA**
  - > Several dish antennas simply replaced by one AESA antenna
    - Output is at IF 70MHz; tuning, preD combiner and regulation performed inside AESA
      - 1 physical output per TM signal
      - When receiving Multiple TM signals (40 or higher), need 40+ physical links
    - Require direct connection to the receiver / demod (RF transport / switching not needed)

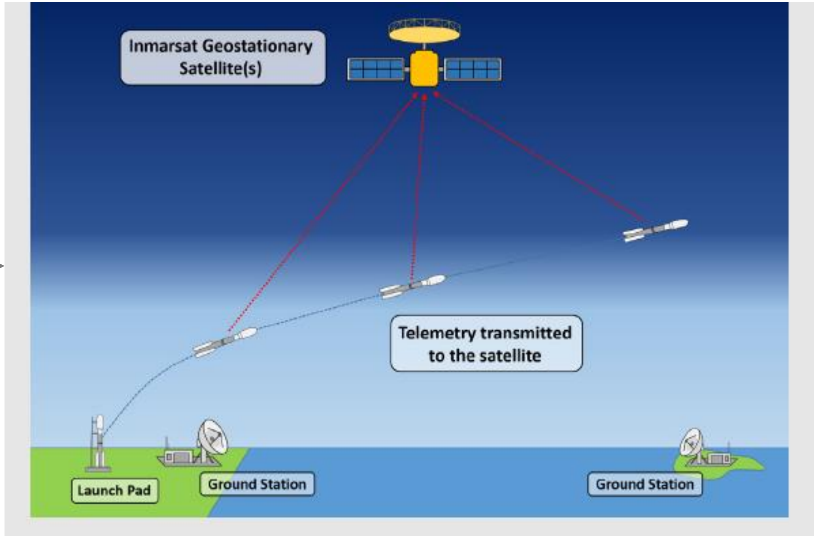


Space-Based TM

Space based Telemetry

- Concept
  - Use satellite to cover parts of the mission when other Telemetry assets do not have visibility





- NASA TDRS
  - Historical constellation used since Space Shuttle launches
  - Going to be decommissioned and replaced by Commercial solutions (NASA CSP program)
- Solutions
  - GEO satellite or LEO constellation (lower latency), closer to a ReRad Aircraft

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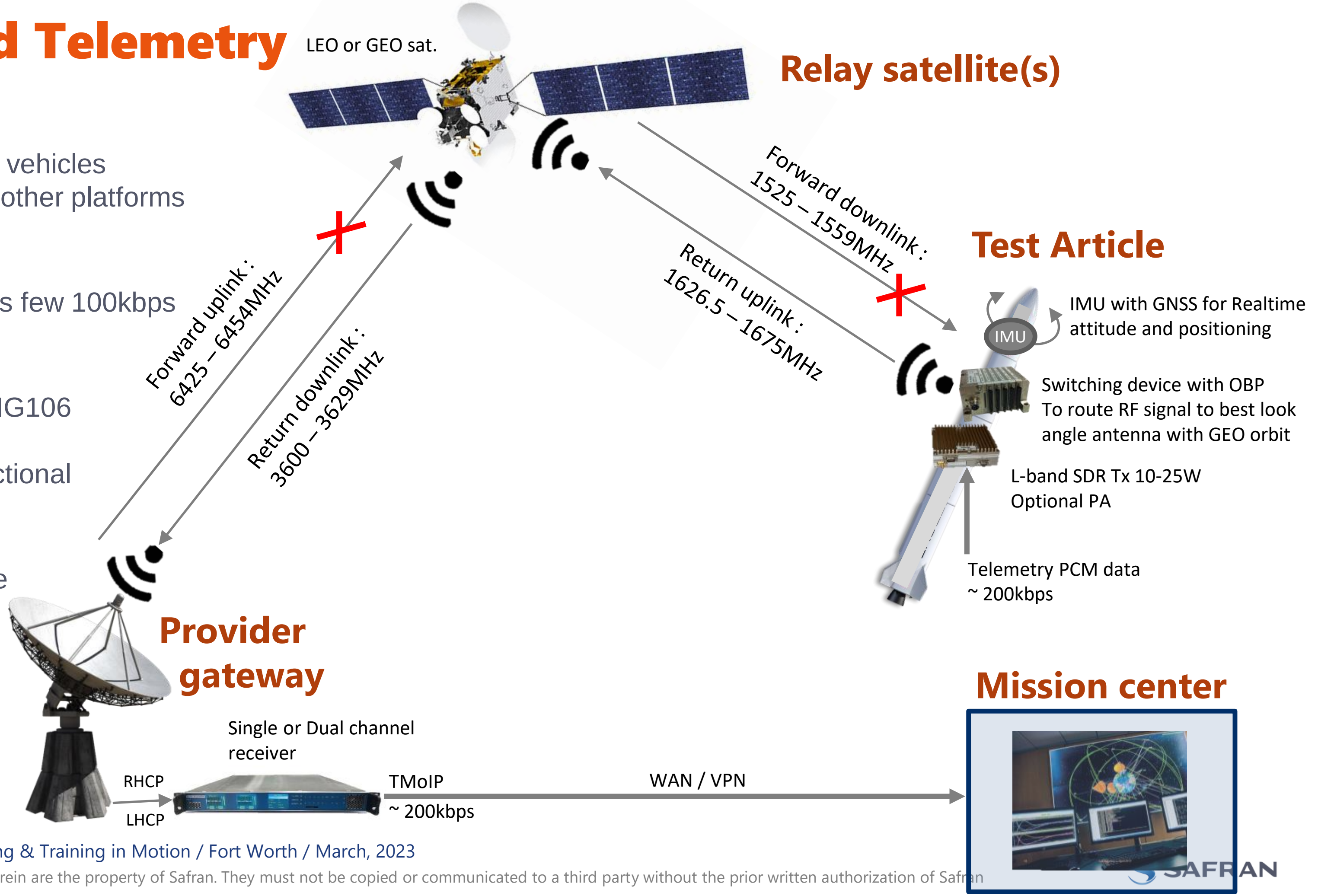
Space based Telemetry

Test articles
- Designed for launch vehicles
- But can be used tor other platforms

Throughput
- Low BW so bit rate is few 100kbps

RF band
- Same or close to IRIG106 L and S-band
- Provision for bi-directional

Real-time
- Data delivered to the “customer” MCC In real-time.
- Latency depends on type of satellites
  - 500ms (GEO)
  - 10ms (LEO)



TMoIP (IRIG 218-20) Standard and use cases

TeleMetry Over IP (TMoIP) standard (IRIG218-20)

- **Before 218-20 => 218-10/P**
  - > Standard leaving to much room for interpretation to allow vendor interoperability
  - > TMoIP mainly for "pseudo-wire" to transport PCM over network to have it reconstructed at the other end.
    - 2 protocols : Simple UDP or RTP
  - > Did not allow direct consumption of the TMoIP by a consumer (ie a decom, a BSS,…)
    - Lack embedded time, quality…
- **IRIG218-20**
  - Timestamp added (64bits more in header – 4 to 12 bytes)
    - Allows detecting any default in the TMoIP stream
  - Throughput + 2 new Payload types
    - Throughput = No frame alignment
    - PCM frame aligned = packed (ie payload starts with Sync. word)
    - DQE frame aligned, (ie payload starts with 48bits of DQE)

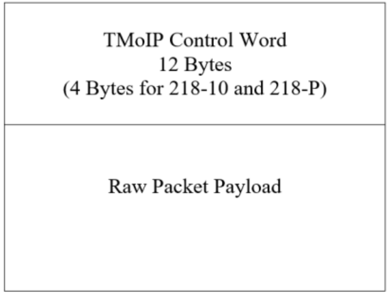


Table 3-5. TMoIP 218-20 Control Word

Field	Bits	Description
VER	4	Version identifier "0010" indicates 218-20
PLD	2	Payload type "00" indicates no frame alignment "01" indicates PCM frame aligned, first or only packet "10" indicates DQE frame aligned, first or only packet "11" indicates frame aligned, continuation packet
mFSS	2	Minor Frame Sync Status (not applicable for PLD = "00") "00" indicates Search "01" indicates Check "10" indicates Lock "11" indicates Flywheel
MFSS	2	Major Frame Sync Status (not applicable for PLD = "00") "00" indicates Search "01" indicates Check "10" indicates Lock "11" indicates Flywheel
RES	5	Reserved
TSR	1	Timestamp Source Reference "0" indicates Universal Coordinated Time "1" indicates International Atomic Time
SEQ NUMBER	16	Sequence Number
TIMESTAMP	64	64-bit Timestamp – PTP format. See Figure 3-6. 32-bit seconds field 2-bit Reserved 30-bit nanoseconds field Prime epoch 00:00 01 Jan 1970

TeleMetry Over IP (TMoIP) standard (IRIG218-20)

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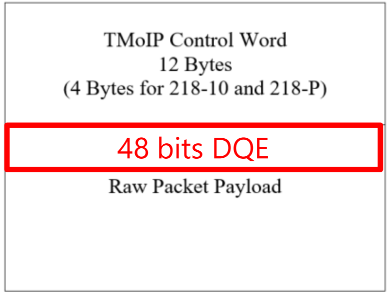

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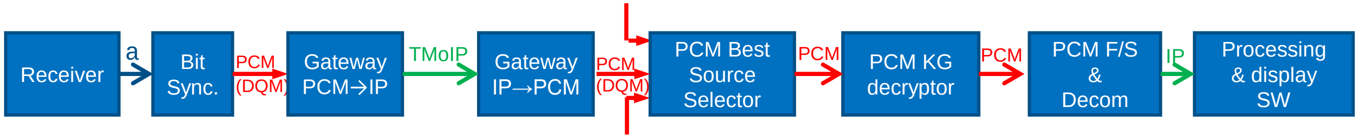
PCM to PCM « pseudo-wire » use case

- **Transport :**
  - PCM (data/clock) moved from one place to another on the range
  - DQM/DQE (IRIG106 or Type2) could be added but this is transparent for the TMoIP gateway in pseudo-wire mode
- **Block diagram:**



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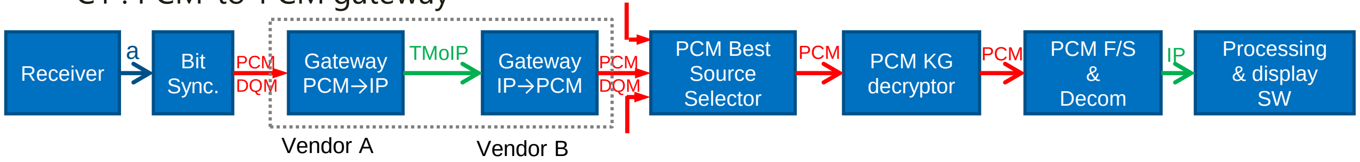
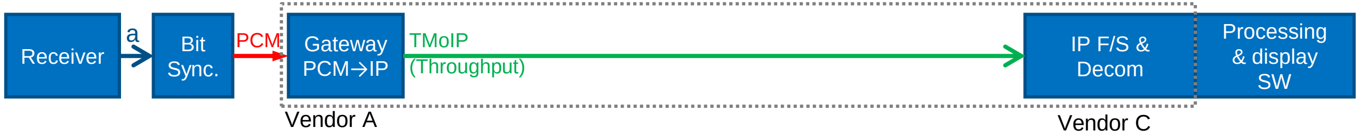
Interoperability on TMoIP gateway boxes

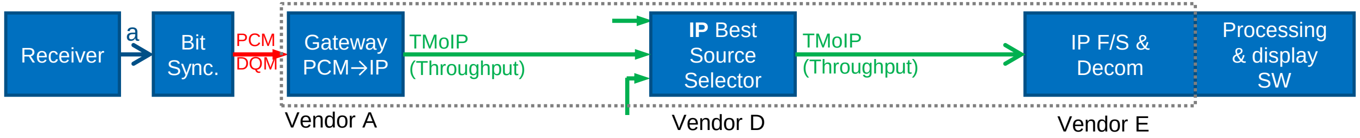
- **Many cases but let's study 4 typical "Gateway" ones :**
  - C1 : PCM-to-PCM gateway



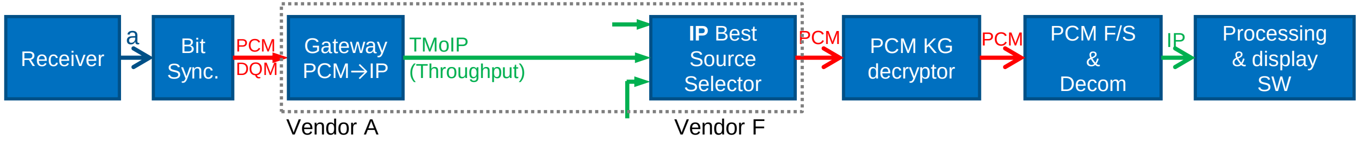
  - C2 : TMoIP to an IP based FS & decom



  - C3 : TMoIP to an IP based Best Source Selector

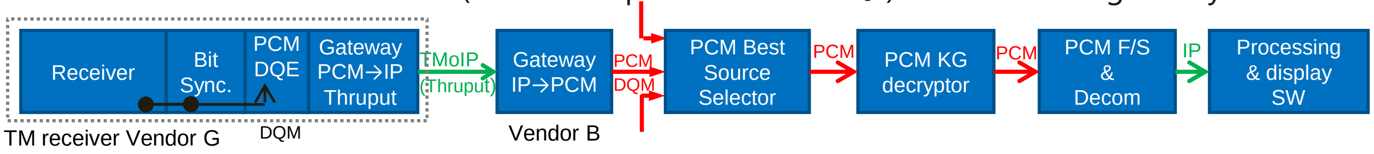


  - C4 : TMoIP to in IP based BSS with KG

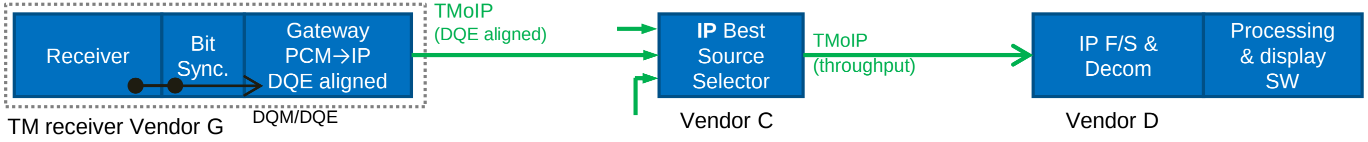


Interoperability on TMoIP gateway inside TM receiver

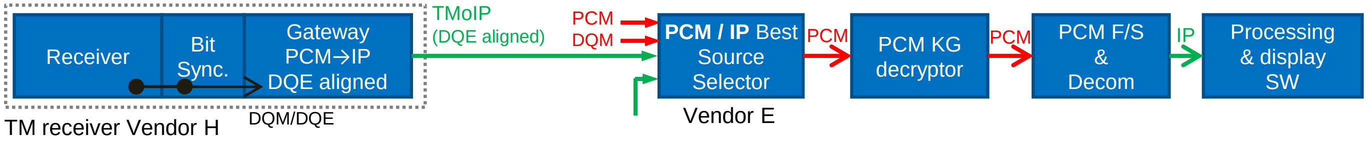
- C5 : Direct TMoIP from Rx (mode Thruput with PCM DQE) to an external gateway



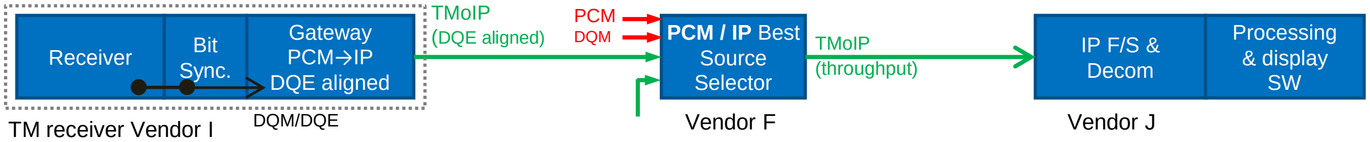
- C6 : Direct TMoIP from Rx (mode DQE aligned) to an IP based BSS, FS & decom



- C7 : Direct TMoIP from Rx (mode DQE aligned) to an hybrid PCM/IP BSS with KG



- C8 : Direct TMoIP from Rx (mode DQE aligned) to an hybrid PCM/IP BSS and IP FS & decom



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Other topics

Other Range of the Future topics

- List of other solutions for Range of the Future
  - Telemetry over IP
    - Use of RCC218-20 for direct TMoIP
    - TMoIP streams network Recorder and Reproducer
  - Multi-channel TM processor
    - Increasing the density of demodulators within a receiver
  - Space-based Telemetry
    - Relying either on GEO or LEO constellation
    - Airborne TM terminal combined with TM receiver in Satellite operator gateway
  - Virtualized Ground station
    - RF over IP
    - Software demodulation and processing
  - Bi-Directional link
    - iNET
    - Independent bands for up & down links
  - Ethernet RCC218-20 (TMoIP) based Decryptor
  - Cellular Based Telemetry
    - Leveraging 5G technology to telemeter down TM data (or also support bi-directional link)

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Thank you!

pm.bastie@safrandatasystemsus.com

TRAINING

Johnny PAPPAS

EVP & CTO

Safran Data Systems

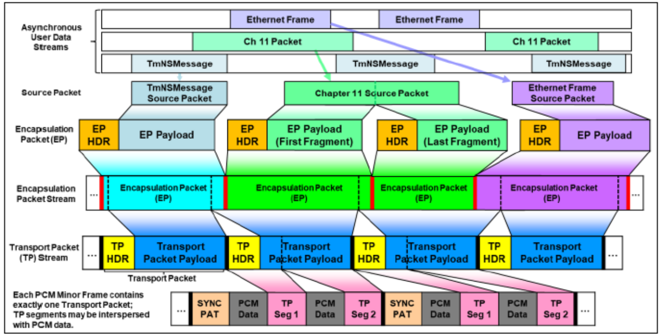

Figure 7-1. Packet Telemetry Overview

Testing & Training in Motion

IRIG 106 - Chapter 7 Packet Telemetry Downlink

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IRIG Standards and Range Commanders Council Documents

IRIG 106 is TELEMETERY STANDARDS
Range Commanders Council Telemetry Group

~~https://www.wsmr.army.mil/RCCsite/Pages/default.aspx~~

https://www.trmc.osd.mil/wiki/display/publicRCC/Public+RCC+Home

IRIG106.org

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IRIG 106 Standard-Packet Telemetry Options

CHAPTERS

CHAPTER 1:	Introduction
CHAPTER 2:	Transmitter and Receiver Systems
CHAPTER 3:	Frequency Division Multiplexing Telemetry Standards
CHAPTER 4:	Pulse Code Modulation Standards
CHAPTER 5:	Digitized Audio Telemetry Standard
CHAPTER 6:	Recorder & Reproducer Command and Control
CHAPTER 7:	Packet Telemetry Downlink
CHAPTER 8:	Digital Data Bus Acquisition Formatting Standard
CHAPTER 9:	Telemetry Attributes Transfer Standard
CHAPTER 10:	Digital On-board Recorder Standard
CHAPTER 11:	Recorder Data Packet Format Standard
CHAPTER 21:	Telemetry Network Standard Introduction
CHAPTER 22:	Network-Based Protocol Suite
CHAPTER 23:	Metadata Configuration
CHAPTER 24:	Message Formats
CHAPTER 25:	Management Resources
CHAPTER 26:	TmNSDataMessage Transfer Protocol
CHAPTER 27:	Radio Frequency Network Access Layer
CHAPTER 28:	Radio Frequency Network Management

C7

Chapter 9/10/11

TMNS

Range Commanders Council-IRIG

Inter-Range Instrumentation Group

Documents of Interest

- 106-20 Telemetry Standards
- 120-08 Radio Frequency Handbook
- 121-13 Instrumentation Engineers Handbook
- 123-16 IRIG 106 Chapter 10 Programmers Handbook
- 124-19 TMATS Handbook

- **IRIG 106 Packet Telemetry Instrumentation Handbook (C7)** **(to published 2024**

What problem are solved with Packet Telemetry

- Transmitting data to the ground that is asynchronous or the measurement length is not fixed
- Examples
  - Compressed Video
  - Asynchronous High Speed Channels
    - Ethernet
    - Fibre Channel
    - 1394
    - 1553
    - ARINC 429
    - RS-232 & 422 UART data
  - Data Sources that have totally different sample times where one source sample rate is NOT an integer relationship to the other data
  - Anything that does not fit well into a fixed periodic occurring time slot (TDM Time Division Multiplex)

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Chapter 4 Sampling Complexity

These are time slots to insert measurements

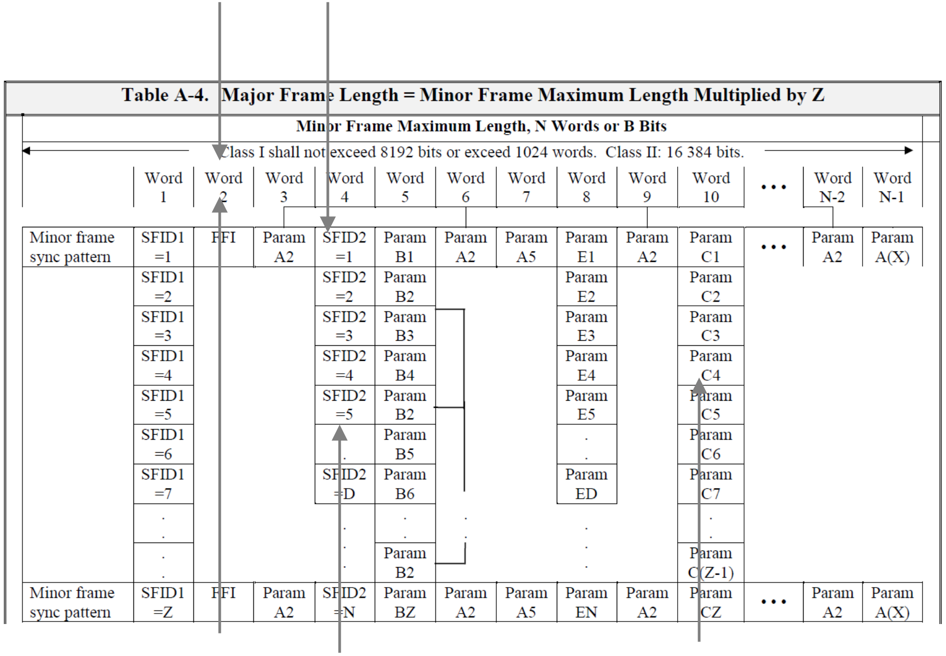

Table A-4. Major Frame Length = Minor Frame Maximum Length Multiplied by Z

Minor Frame Maximum Length, N Words or B Bits

Class I shall not exceed 8192 bits or exceed 1024 words. Class II: 16 384 bits.

	Word 1	Word 2	Word 3	Word 4	Word 5	Word 6	Word 7	Word 8	Word 9	Word 10	. . .	Word N-2	Word N-1
Minor frame sync pattern	SFID1 =1	FFI	Param A2	SFID2 =1	Param B1	Param A2	Param A5	Param E1	Param A2	Param C1	. . .	Param A2	Param A(X)
	SFID1 =2			SFID2 =2	Param B2			Param E2		Param C2			
	SFID1 =3			SFID2 =3	Param B3			Param E3		Param C3			
	SFID1 =4			SFID2 =4	Param B4			Param E4		Param C4			
	SFID1 =5			SFID2 =5	Param B2			Param E5		Param C5			
	SFID1 =6			.	Param B5			. .		Param C6			
	SFID1 =7			SFID2 =D	Param B6			Param ED		Param C7			
	. .			. .	. .	. .		. .		. .			
	. .			.	Param B2			.		Param C(Z-1)			
Minor frame sync pattern	SFID1 =Z	FFI	Param A2	SFID2 =N	Param BZ	Param A2	Param A5	Param EN	Param A2	Param CZ	. . .	Param A2	Param A(X)

Example - Vibration Velocity Temp

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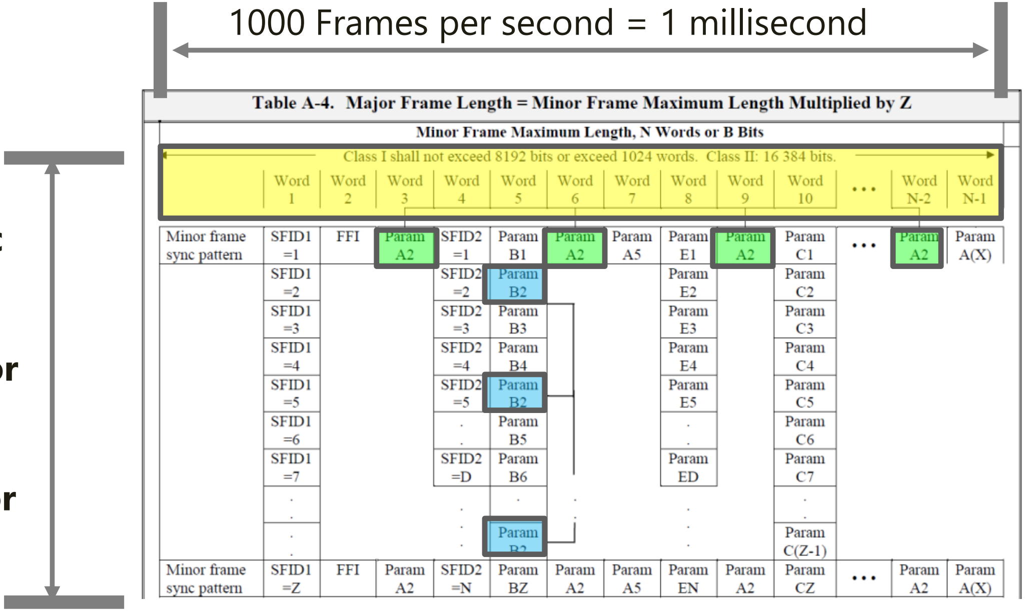
Chapter 4 Frame and Timing

1 Sec

1K Minors Per Major



Major and Minor frame times are the fundamental time period bases
Example1 - If you want 10K Samples per second A2=10 (super comm)
Example1 - If you want 100 Samples per second B2=10 (sub Comm)

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Data Characteristics not ideal for Time Division Multiplex Fixed Position Transport

- Data entities that occur with the substantial size changes from the smallest amount of data to the largest size of data
  - Example Compressed Video
  - Ethernet Packets
  - Message Packets that change sizes

- Data entities that have a substantial change in timing such as irregular changing frequency/rates

What is the efficient way to sample and transport data?

- Continuous Signals => **Periodic sample**
- Async or Variable Speed Data or variable length=> **Asynchronous Sample**

If an Asynchronous Packet arrives at C7 system, you want it to be telemetered as quick as possible!

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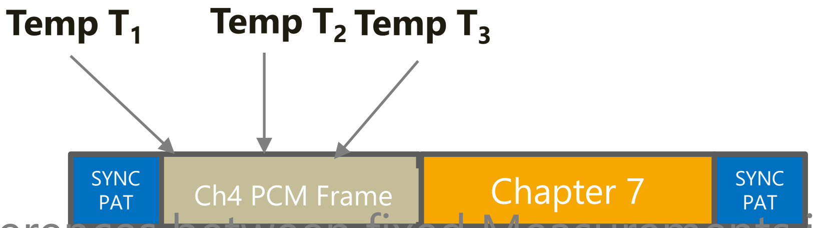
Differences between fixed Measurements in PCM Stream and Packet and Packet transmission of Data



Differences between fixed Measurements in PCM Stream and Packet
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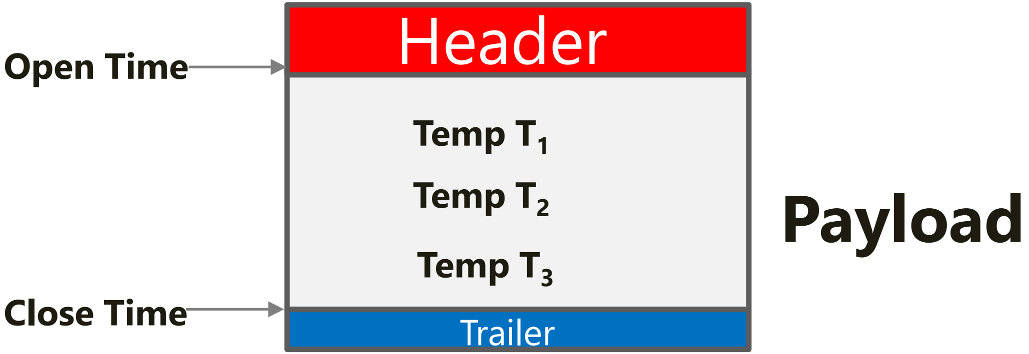
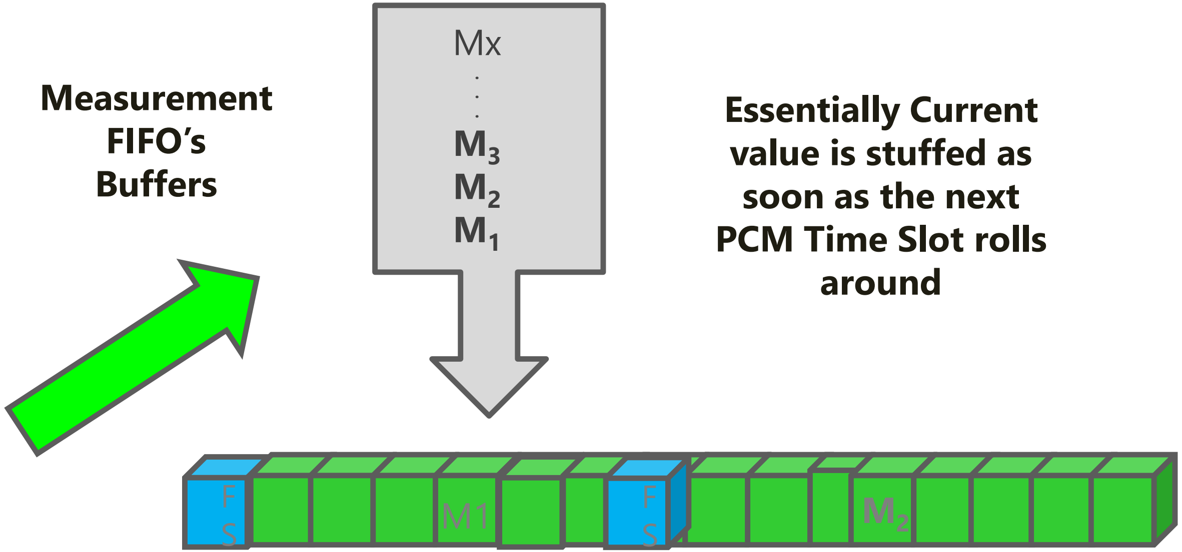


PCM Latency

- **Chapter 4 PCM and Latency**

Measurement FIFO's Buffers



Essentially Current value is stuffed as soon as the next PCM Time Slot rolls around

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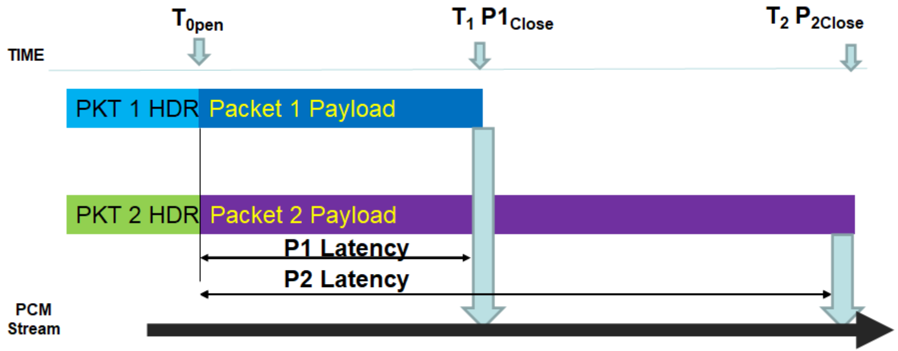
Look at basics again - Packet Latency and Reducing Latency

- **Packets collect various amounts of data**

Example



- **The longer a packet is open collecting data over time, the latency of the data increases**
- **Trade off- Reduce Latency using smaller packet sizes, but ratio of overhead vs payload increases**

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Fundamental Objectives Ground Side for Packet Telemetry (C7)

- Minimize Switching Cost
  - Ground Side
    - Had to be 100% compatible with existing ground-based hardware
      - **RF Antennas and Receivers**
      - **PCM Front Ends**
  - Ground Receiving
    - No change in data handling operations
    - ***Serves nicely as a gateway to distribute data on the ground***
  - ***MOST IMPORTANT- Minimal Switching Cost***

  - ***Had to be compatible with a Typical PCM Front End Decom***

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Maturity of Chapter 7

- Extremely quick implementation and adoption of C7
- No known programs experienced bad performance where Chapter 7 was not successful supporting mission objectives
- C7 adopted as the worldwide standard for Packet Telemetry Downlink
- Being used on both Rotary and Fixed Wing Aircraft very successfully
- DOD Large programs extensive use

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How is Chapter 7 Described

CHAPTER 7

Packet Telemetry Downlink

Chapter 7 Significant Releases

106 15 Release – packet transmission only

106 17 Release- Chapter 4 Time Division Multiplexed Data
+ Packet Transport

106 19 Release- Changed the terminology

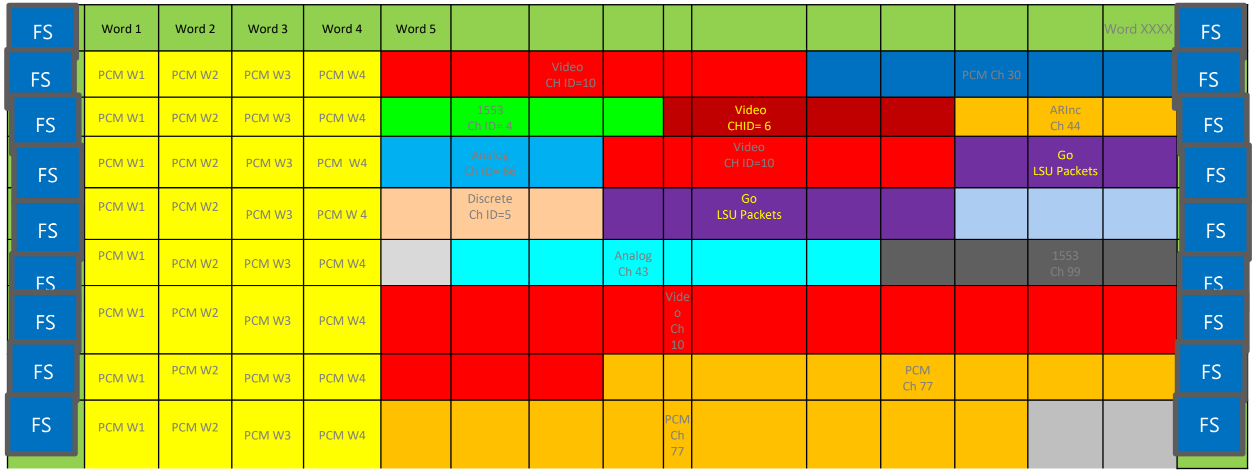
Don't read 106 19 Chapter 7, If you do, you will think your stupid!

How does a PCM Stream look like with Chapter 2 Time Division Multiplexed Data and Chapter 7 Packet Telemetry

NOTE: NO need to address timing for packets, YOU ONLY NEED TO ALLOCATE SUFFICIENT BANDWITH

Fixed Position Measurements/Sample

Packets-iNet, C10, User Defined, Ethernet



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Let's look at Different Types of Packets that can be transported using Packet Telemetry

THE PACKET YOU WANT TO TM DOWNLINK OVER AN RF LINK IS CALLED A USER PACKET!

Let Look little deeper at User/Source Data Packets that C7 can Transport

Types USER SOURCE PACKETS suitable for C7 Packet Telemetry Downlink

Chapter 10 Packets

TMNS

Ethernet Packets- IP Packets or MAC Layer

Application Specific or User Defined Packets or Datagrams

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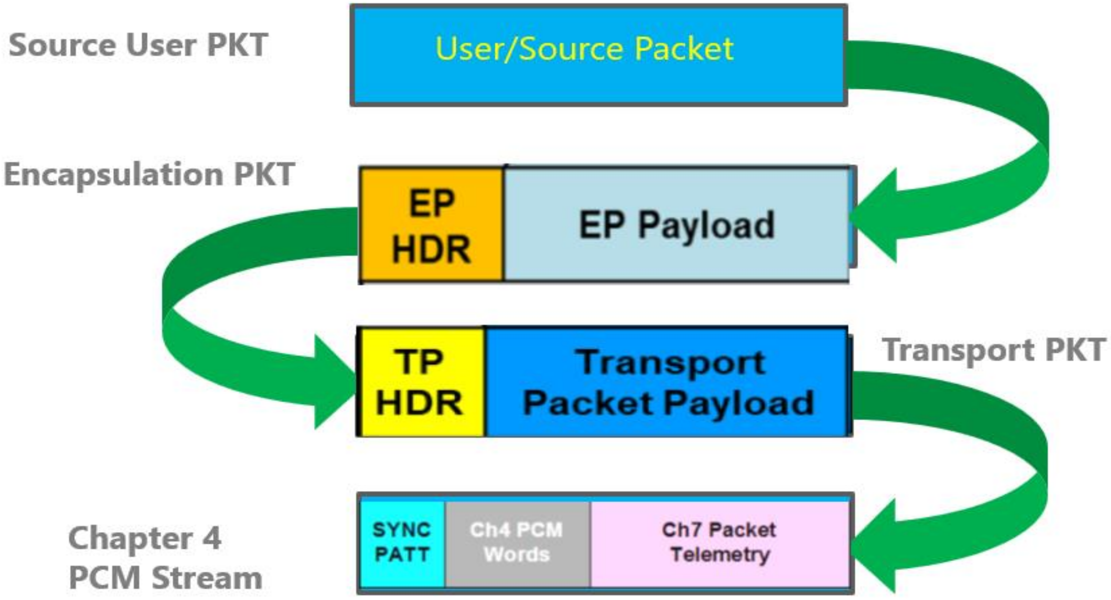
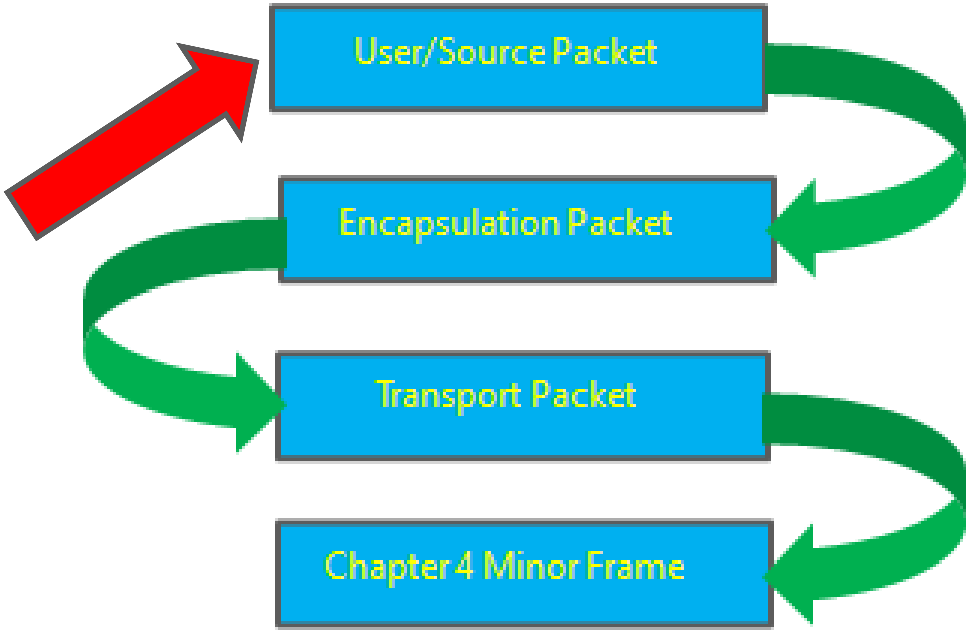
Let's look at the Different Layers of Chapter 7 Packet Handling and transport

Start with User Packets and Source Packets

You can visualize C7 consisting of 4 Transport Layers



Source Packets Layer 1



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Chapter 7 - Layer 3 – Source Packets

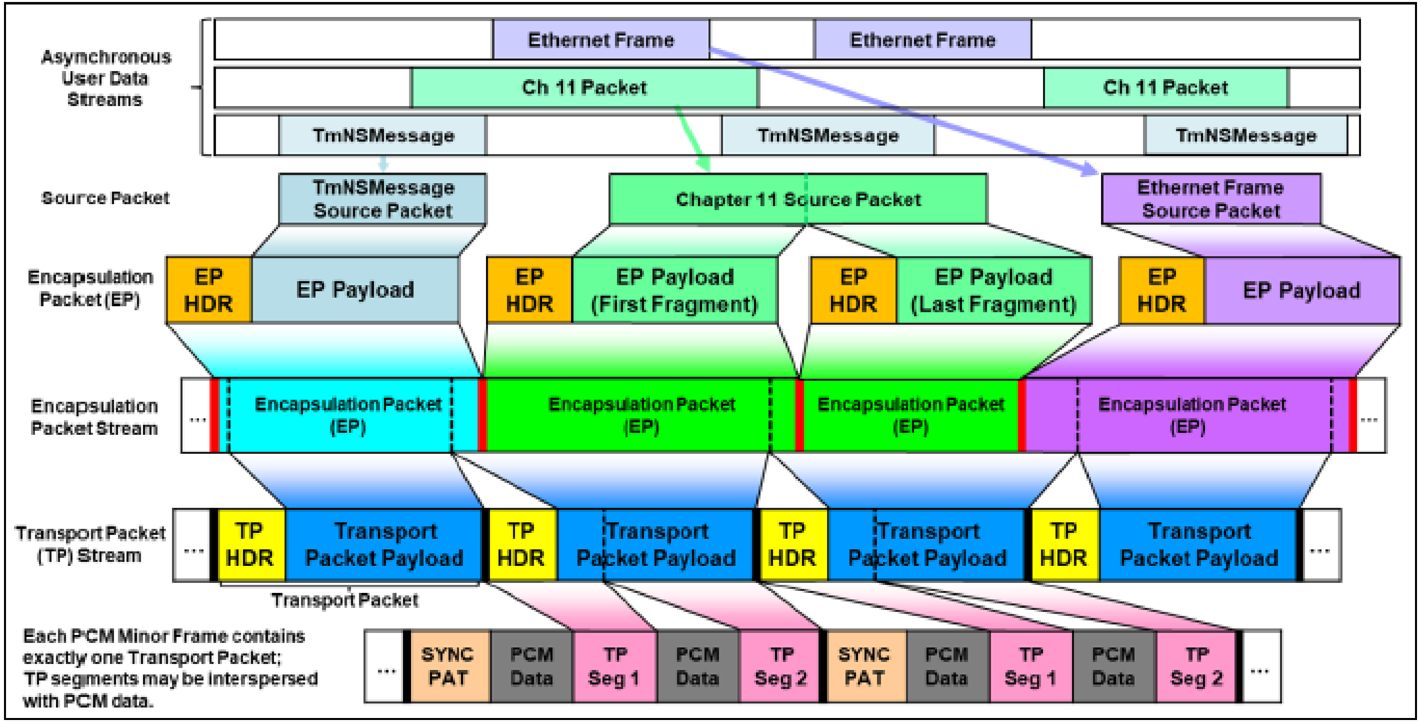


Figure 7-1. Packet Telemetry Overview

C11 Packets Structure

Telemetry Standards, IRIG Standard 106-20 Chapter 11, July 2020

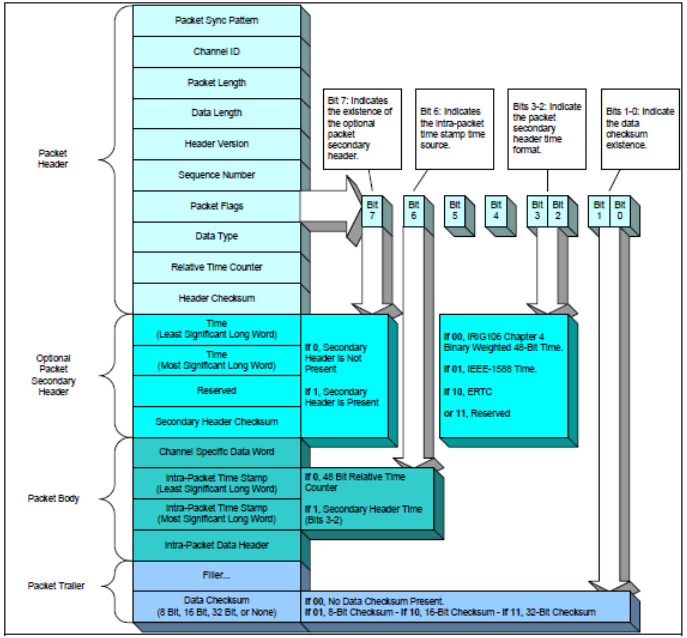


Figure 11-1. Overall Packet Structure

Table 11-1. General Packet Structure

PACKET SYNC PATTERN	Packet Header
CHANNEL ID	
PACKET LENGTH	
DATA LENGTH	
DATA TYPE VERSION	
SEQUENCE NUMBER	
PACKET FLAGS	
DATA TYPE	
RELATIVE TIME COUNTER	
HEADER CHECKSUM	

Chapter 11Packet Data Types

Table 11-4. Data Type Names and Descriptions

Packet Header Value	Data Type Name	Data Type Description	Current Data Type Version
0x00	Computer-Generated Data, Format 0	User-Defined	0x06
0x01	Computer-Generated Data, Format 1	Setup Record	0x09
0x02	Computer-Generated Data, Format 2	Recording Events	0x06
0x03	Computer-Generated Data, Format 3	Recording Index	0x06
0x04	Computer-Generated Data, Format 4	Streaming Configuration Records	0x08
0x05 – 0x07	Computer-Generated Data, Format 5-Format 7	Reserved for future use	0x06
0x08	PCM Data, Format 0	Reserved for future use	0x06
0x09	PCM Data, Format 1	Chapter 4, 7, or 8	0x06
0x0A	PCM Data, Format 2	DQE PCM	0x09
0x0B - 0x0F	PCM Data, Format 3 - Format 7	Reserved for future use	0x06
0x10	Time Data, Format 0	Reserved for future use	0x06
0x11	Time Data, Format 1	RCC/Global Positioning System (GPS)/Relative Time Counter (RTC)	0x06
0x12	Time Data, Format 2	Network Time	0x08
0x13-0x17	Time Data, Format 2-Format 7	Reserved for future use	0x06
0x18	MIL-STD-1553 Data, Format 0	Reserved for future use	0x06
0x19	MIL-STD-1553 Data, Format 1	MIL-STD-1553B Data	0x06
0x1A	MIL-STD-1553 Data, Format 2	16PP194 Bus	0x06
0x1B-0x1F	MIL-STD-1553 Data, Format 3-Format 7	Reserved for future use	0x06
0x20	Analog Data, Format 0	Reserved for future use	0x06
0x21	Analog Data, Format 1	Analog Data	0x06
0x22-0x27	Analog Data, Format 2-Format 7	Reserved for future use	0x06
0x28	Discrete Data, Format 0	Reserved for future use	0x06
0x29	Discrete Data, Format 1	Discrete Data	0x06
0x2A-0x2F	Discrete Data, Format 2-Format 7	Reserved for future use	0x06
0x30	Message Data, Format 0	Generic Message Data	0x06
0x31-0x37	Message Data, Format 1-Format 7	Reserved for future use	0x06
0x38	ARINC-429 Data, Format 0	ARINC-429 Data	0x06
0x39- 0x3F	ARINC-429 Data, Format 1-Format 7	Reserved for future use	0x06
0x40	Video Data, Format 0	MPEG-2/H.264 Video	0x06
0x41	Video Data, Format 1	ISO 13818-1 MPEG-2	0x06
0x42	Video Data, Format 2	ISO 14496-10 MPEG-4 Part 10 AVC/ITU H.264	0x06
0x43	Video Data, Format 3	MJPEG	0x07
0x44	Video Data, Format 4	MJPEG-2000	0x07
0x45-0x47	Video Data, Format 3-Format 7	Reserved for future use	0x06
0x48	Image Data, Format 0	Image Data	0x06
0x49	Image Data, Format 1	Still Imagery	0x06
0x4A-	Image Data, Format 2	Dynamic Imagery	0x06
0x4B-0x4F	Image Data, Format 3-Format 7	Reserved for future use	0x06
0x50	UART Data, Format 0	UART Data	0x06
0x51-0x57	UART Data, Format 1-Format 7	Reserved for future use	0x06
0x58	IEEE 1394 Data, Format 0	IEEE 1394 Transaction	0x06
0x59	IEEE 1394 Data, Format 1	IEEE 1394 Physical Layer	0x06
0x5A-0x5F	IEEE 1394 Data, Format 2-Format 7	Reserved for future use	0x06
0x60	Parallel Data, Format 0	Parallel Data	0x06
0x61-0x67	Parallel Data, Format 1-Format 7	Reserved for future use	0x06
0x68	Ethernet Data, Format 0	Ethernet Data	0x07
0x69	Ethernet Data, Format 1	Ethernet UDP Payload	0x06
0x6A-0x6F	Ethernet Data, Format 2-Format 7	Reserved for future use	0x06
0x70	TSPI/CTS Data, Format 0	GPS NMEA-RTCM	0x06
0x71	TSPI/CTS Data, Format 1	EAG ACMI	0x06
0x72	TSPI/CTS Data, Format 2	ACTTS	0x06
0x73- 0x77	TSPI/CTS Data, Format 3-Format 7	Reserved for future use	0x06
0x78	Controller Area Network Bus	CAN Bus	0x06
0x79	Fibre Channel Data, Format 0	Fibre Channel Data	0x07
0x7A	Fibre Channel Data, Format 1	Fibre Channel Data	0x08
0x7B – 0x80	Fibre Channel Data, Formats 2-7	Reserved for future use	0x08

Chapter 24- TMNS Message (IRIG 106 Chapter 24)

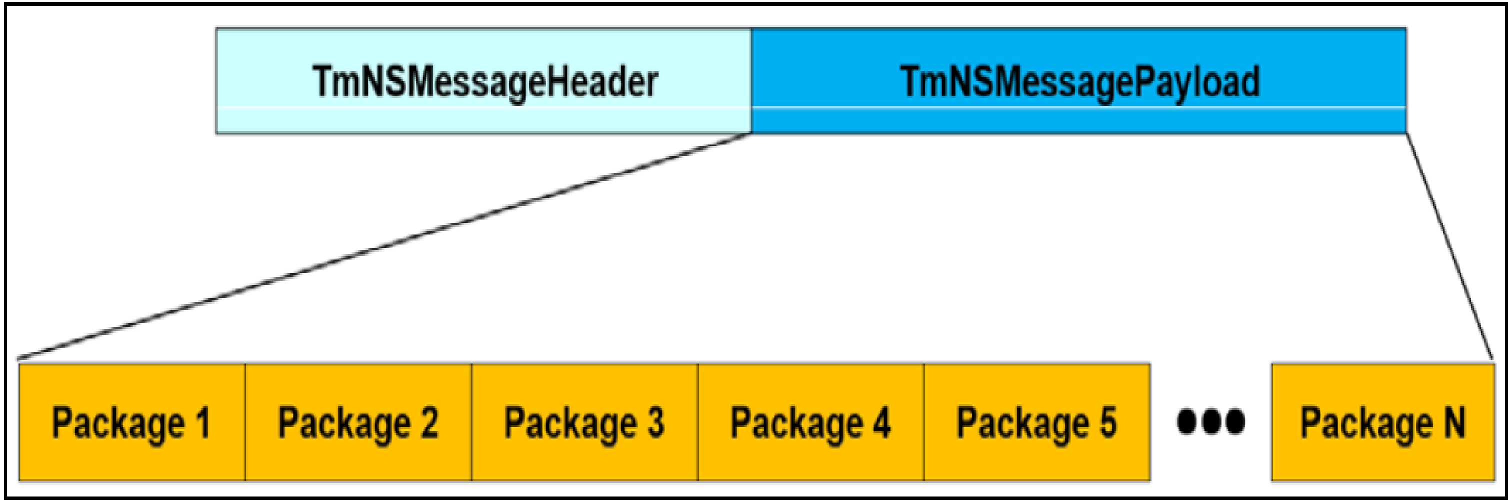
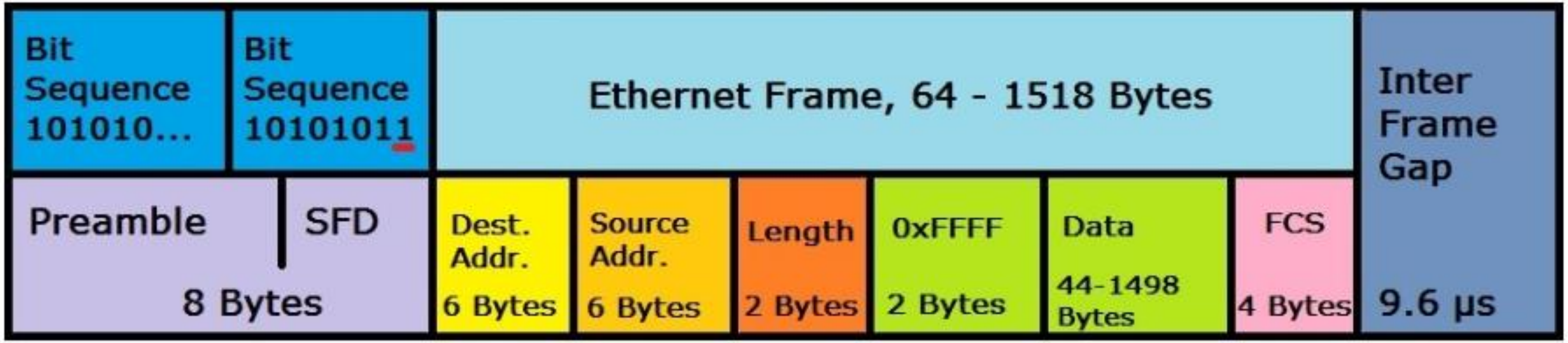


Figure 24-3. TmNSMessage Structure

RAW Ethernet MAC Frame Packet

Ethernet 802.3raw



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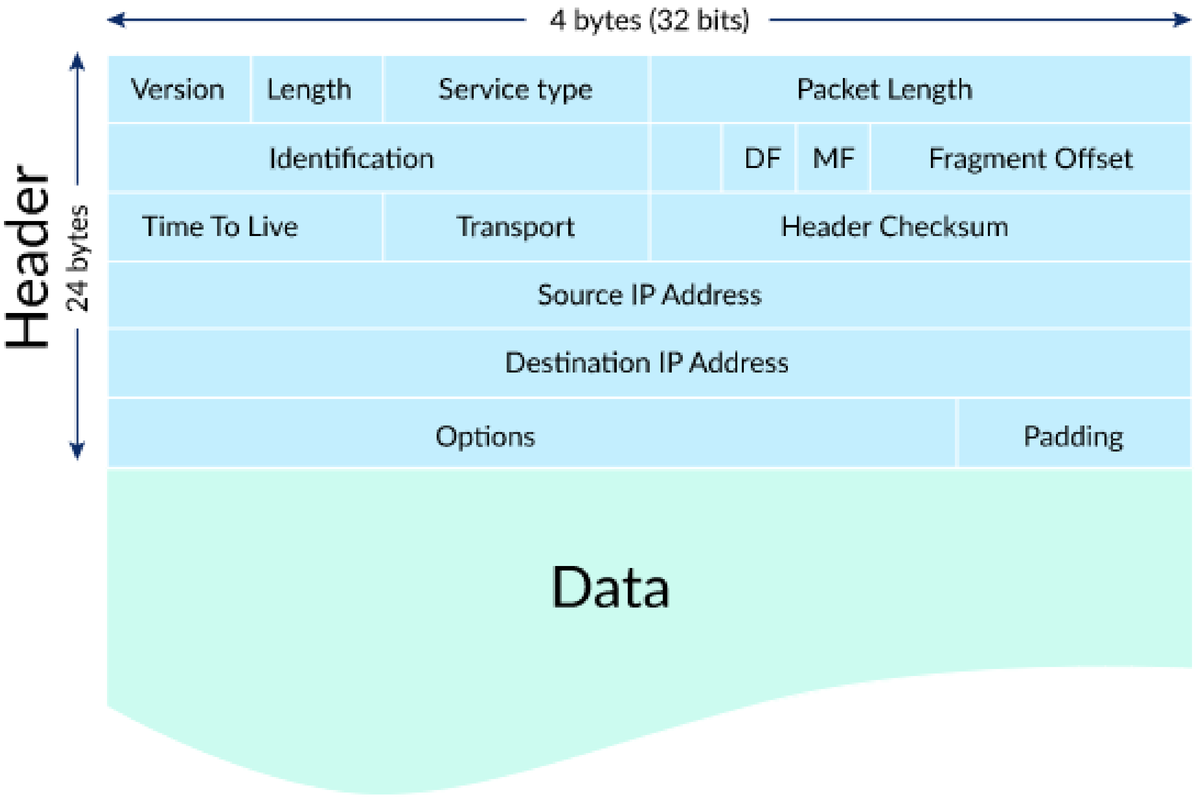
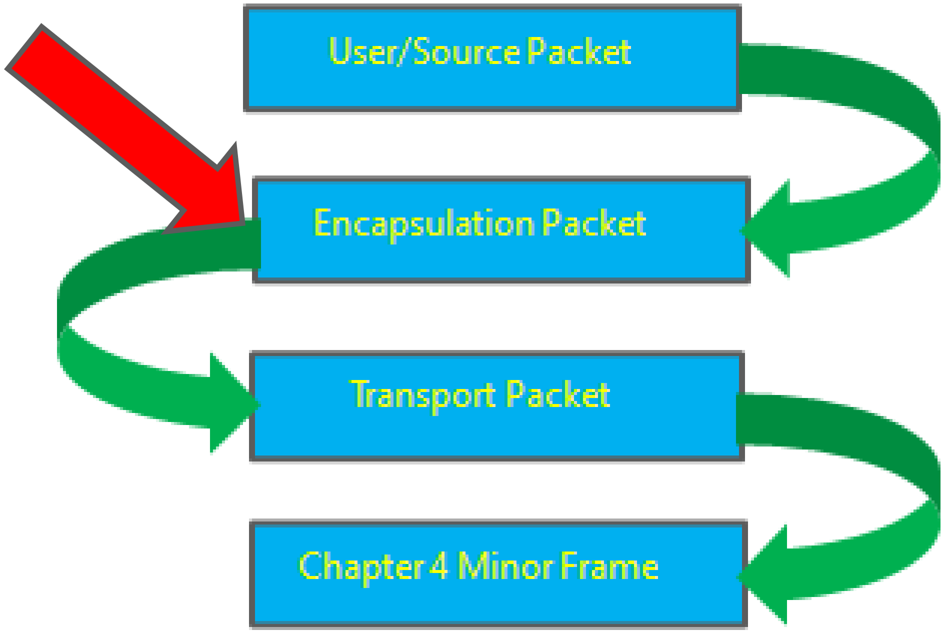
IP Packet



4 bytes (32 bits)
Header
24 bytes
Version
Length
Service type
Packet Length
Identification
DF
MF
Fragment Offset
Time To Live
Transport
Header Checksum
Source IP Address
Destination IP Address
Options
Padding
Data

Encapsulation Packets Layer 2



Chapter 7 - Layer 2 - Encapsulation Packets

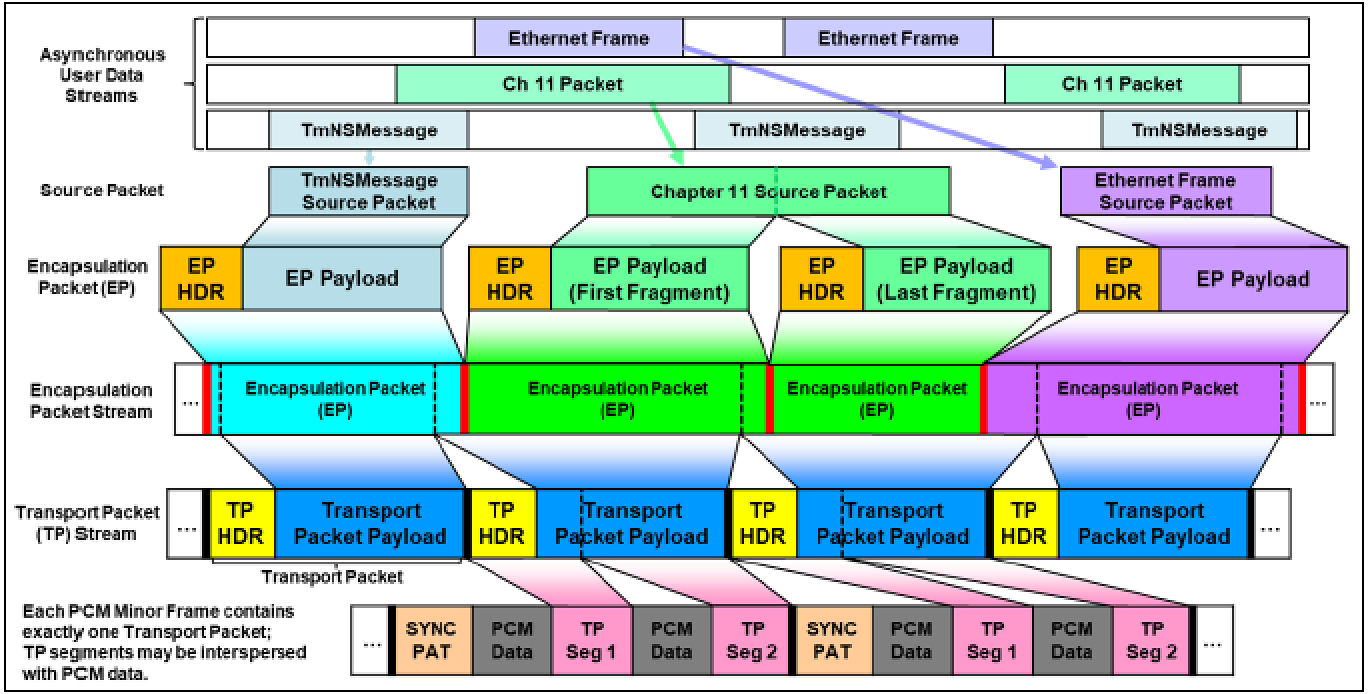
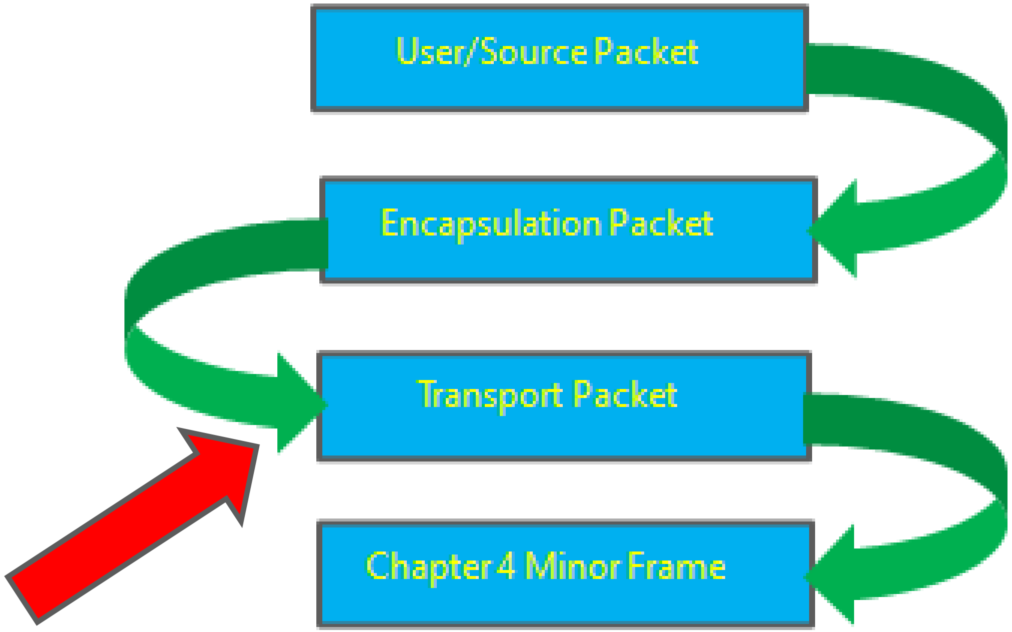


Figure 7-1. Packet Telemetry Overview

Transport Packets Layer 3



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Chapter 7 - Layer 3 – Transport Packet

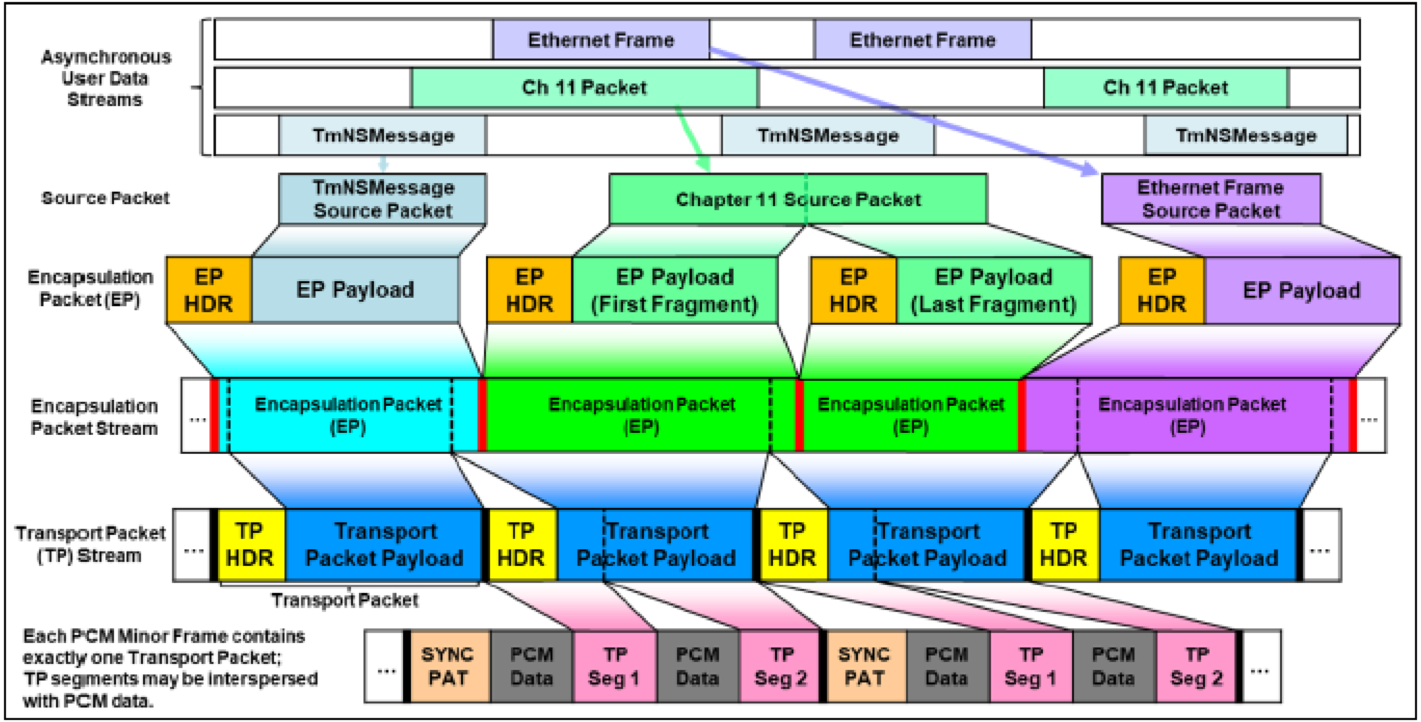
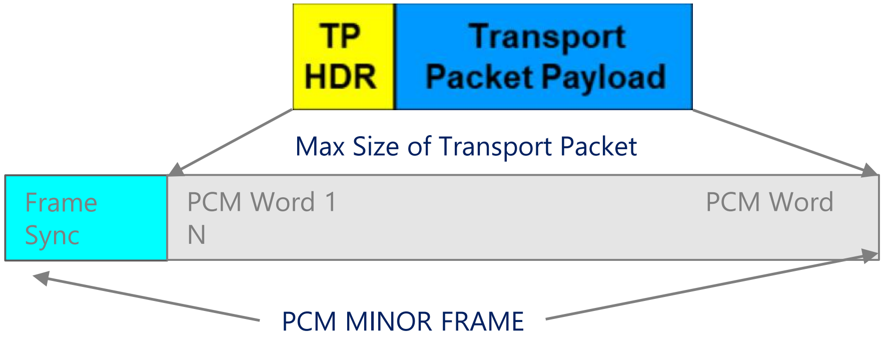


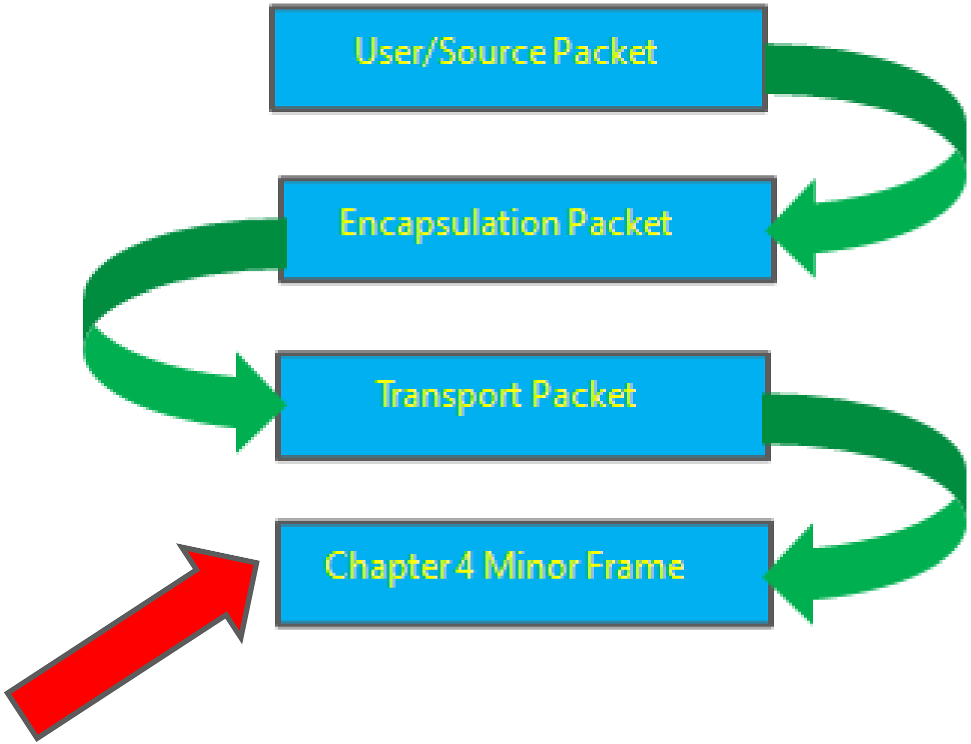
Figure 7-1. Packet Telemetry Overview

Things to remember about Transport Packet

There is only one Transport Packet Per PCM Minor Frame

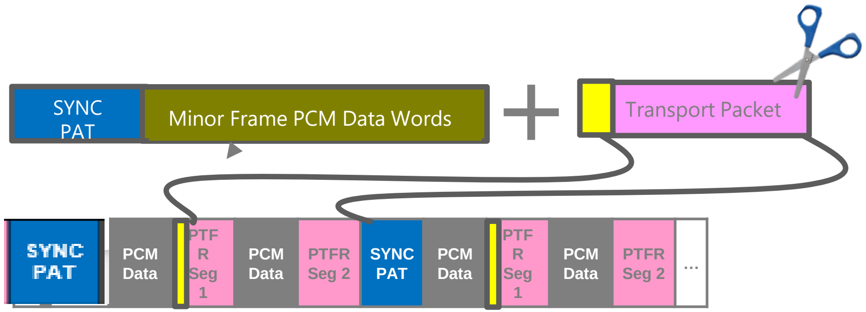


Chapter 4 PCM Stream Layer 4



IRIG106-17 Chapter 4/7 PCM Stream

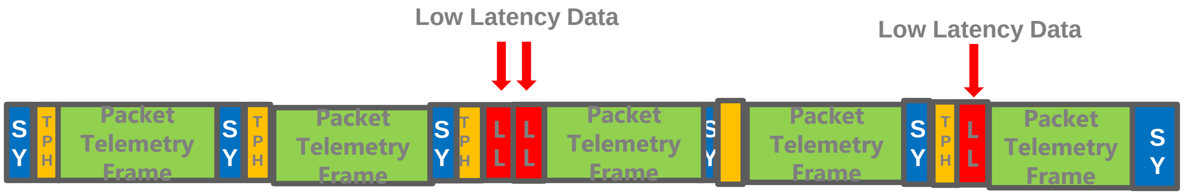
- **Define a standard IRIG106 Chapter 4 Class 2 PCM frame**
- **Designate one or more contiguous segments of PCM Minor Frame words in the PCM frame to contain Chapter 7 Packet Telemetry Data Frame**



Note: 1 Transport Packet per Minor Frame!

NOW - Chapter 7 and Low Latency

- Chapter 7 provides an ability to flag a packet as low latency
- Low Latency packets take precedence for being inserted into the Transport Packet
- LL Packets get inserted into the PCM Stream at the beginning of the Transport Packet
- Low Latency Packets must be smaller than Transport Packet Payload (they can't extend beyond Packet Transport Frame
- NOTE: IT IS THE ONLY TIME A PACKET CAN BE INSERTED BETWEEN FRAGMENTED SOURCE PACKETS



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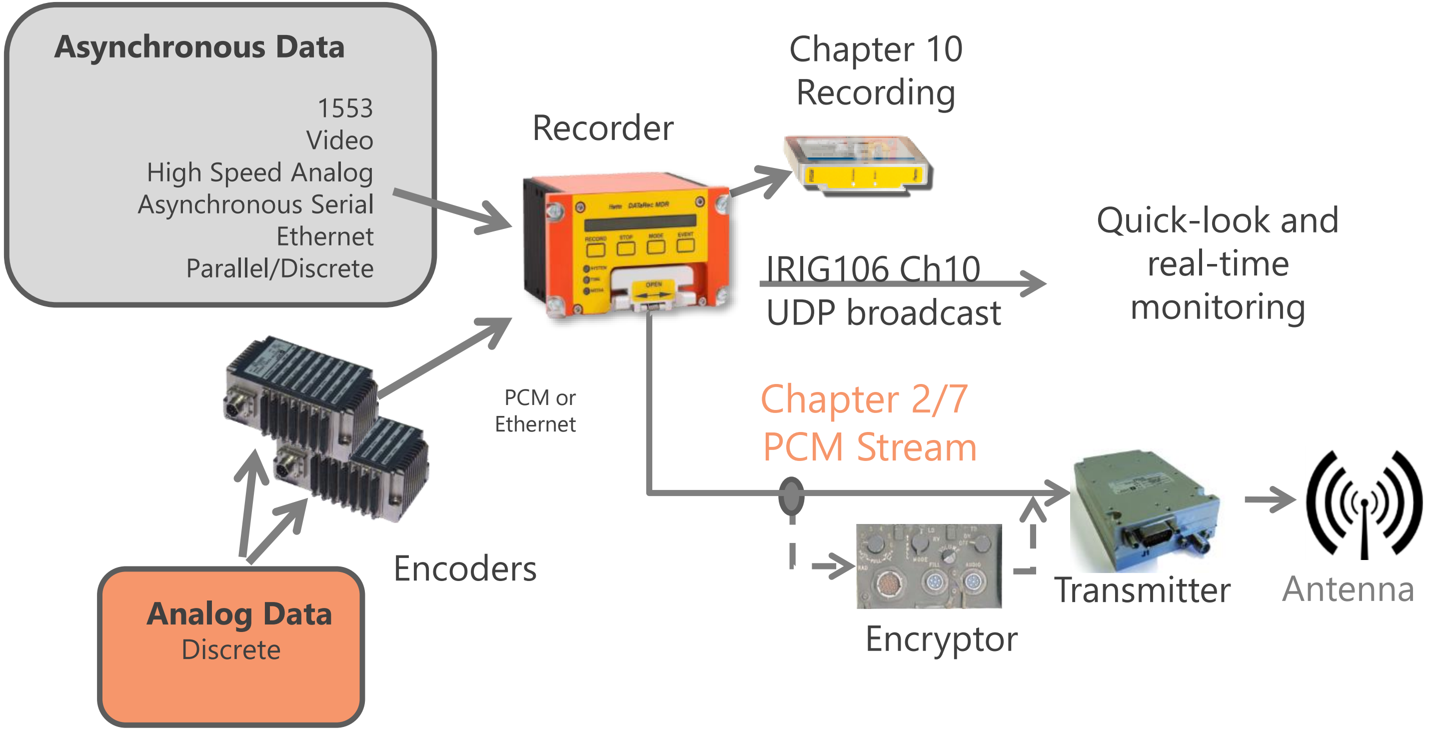
Let’s look at a Chapter 7 System

Popular Chapter 7 Downlink Airborne Configuration



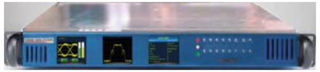
METHOD 1 - PCM Data over RF Carrier

Method 1: PCM Stream over RF using: FM, SOQPSK, or CPM Modulation

Legacy Method 1

RF Original C4 PCM Stream to Ground using ARTM Modulated RF Stream

RF Receiver Demodulated Signal



Original PCM Stream

PCM Data + Clk

PCM Front End + Recorder

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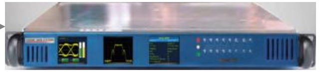
METHOD 2- C11 PCM Packet using C7 as the Transport over RF Carrier

Method 2:
Chapter 7 Transport of C11 PCM Packet containing a PCM C4 Stream over a RF Link to Ground

Chapter 11 PCM Packet

Chapter 7 Gateway C7 TO Native PCM Signals

RF Receiver Demodulated Signal



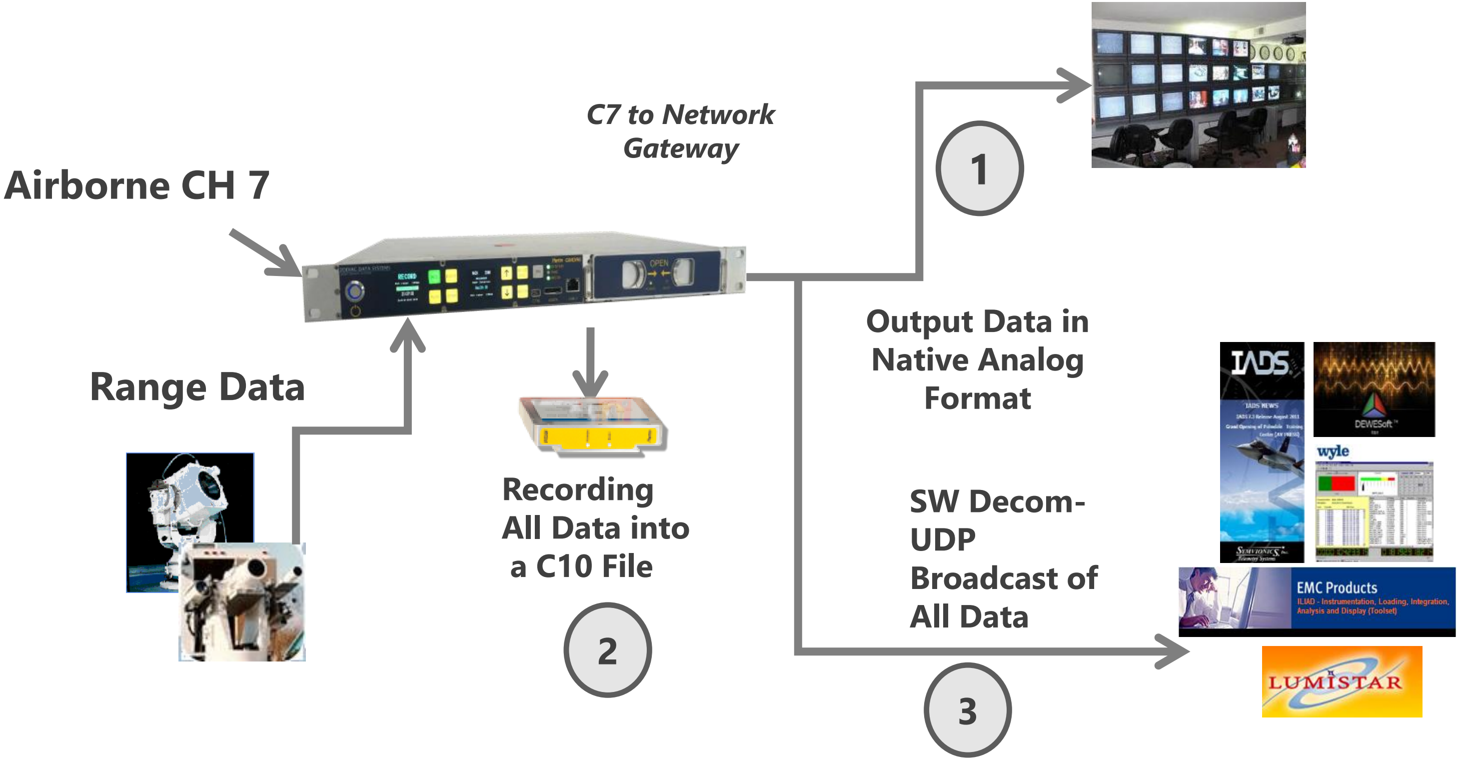
PCM Data

PCM Front End

PCM Clock

.Publish Live Stream C11 PCM Packets

Another view Typical Ground Rec, Soft Decom, Live Play



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UDP Data Gateway Distribution on the Ground

Note: - C10 Packets transmitted with no UDP Ethernet Overhead
- For C10/11 UDP on Ground, IP's defined on the Ground

Performance cont.

- Typical mission data dropouts are typically not random bit errors, they are short or long data gap dropouts

- Approximate BER of 10^{-6} performance gives acceptable TM downlink even with large packets such as highly compressed video streams

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C7 Summary

- Totally compatible with TM encryptor, decryptor, transmitters, receivers, bit syncs
- Ch11/10 Telemetry Downlink can greatly simplify TM downlink process
  - Packet Telemetry eliminates tedious time dependent placement into a PCM Minor Frame
  - Packet Filtering is the key process so you don't loose data due to PCM RF downlink limited bit rates.
- Minimal testing required to setup mission
- Switching cost is low
- Ideal for HD recording and SD Video downlink
- Suitable for Ethernet gateway applications.
- Low latency is achievable (20 ms, except Video)
- Ideal for missions with quick reaction dynamic data requirements
- In operation by many flight-test centers world wide, and field proven and tested by multiple additional places

THANK YOU!

Johnny PAPPAS
johnny.pappas@safrandatasystemsus.com