IRIG106-CHAPTER 7 IN PRACTICE – A REAL USE CASE

Stéphane Duguet, Jean-Guy Pierozak
NEXEYA Test Range Activities
NEXEYA France, Route d'Elne 66200 Montescot, FRANCE

jean-guy.pierozak@hensoldt.fr
stephane.duguet@hensoldt.fr

Abstract: Chapter 7 methodology was introduced in IRIG106 in 2015 with the purpose of simplifying the on-board architecture while still using legacy Chapter 4 hardware on ground. On top of that, this new protocol benefits from the growing use of the more and more popular Chapter 10/11 processing softwares. The various on-board data sources are acquired and embedded in a standard Chapter 4 PCM data stream. Then, all the telemetry downlink chain can be reused up to the data processing system in charge of reconstructing the original data streams and dispatching them to the end users. This is where complexity reaches its climax, depending on the use-cases.
The goal of this paper it to present a real-case architecture of a flight test bed whose telemetry system has evolved to IRIG106-15 Chapter 7, and the challenges faced by the ground processing system. It gives insights of return of experience of deployment, performances, benefits and drawbacks of such a system, as well as leads for improvements.

Keywords: IRIG106, Chapter 7, Chapter 10, Chapter 11, De-commutation

1. Introduction

Whatever the type of data and the purpose (aircraft development, flight test, health monitoring on operating flights…), the trend is now to produce and store a large volume of different data. In front of this large panel of formats to process, Aircraft development or flight test people need efficient tools to setup their trials and focus on useful data. In complement to material used by the test range (on-board or on the ground), flight test Data Processing Software (DPS) is a key part of this process.

The main objectives for efficient FTI installation are:

- Ensure the acquisition of different data sources (synchronous and asynchronous):
- Manage an increasing volume of data (high-definition video, high-speed data buses)
- Reduce the time allocated for flight test setup and test campaign preparation
- Provide the best possible performance in front of system and test environment condition (limited telemetry transmission bandwidth)
- Have a long life-time (reuse of old legacy equipment)
- Be compliant with most formats and protocols (IRIG 106, Chapter 4, 10…).
- Propose an easy to handle and efficient data processing software
- Be future proof and compatible with the new trends in telemetry standards (TMoIP…)

Chapter 7 was introduced in 2015 with the following targets:

- Simplification of test installation architecture and ease the setup of the telemetry frame by simplifying the transport of asynchronous data in fixed length PCM frames, at fixed bitrate
- Native data transmission: Chapter10, Raw Ethernet media (video, audio), Ethernet (IENA, INET…)
- Mix of asynchronous and synchronous data management
- Correction of errors (with respect with Golay code)
- Ease of real-time monitoring
- Processing of critical data with high priority
- Law latency data management
- Compatibility with most aircraft processing Chapter 4 ground installations

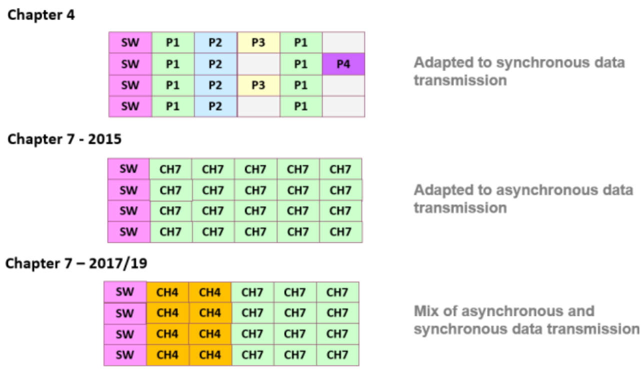

Figure 1 - Chapter 7 format

In few words, Chapter 7 allows transport of raw Ethernet data using specific parts of a chapter 4 frame.
These raw frames are typically used to transport Video Over IP or data through Network protocols such as IENA, iNET etc… Most of time data are single copies of On-board system Ethernet data (system buses, communication between equipment …).
The last evolution of the format introduced a provision for regular Chapter 4 synchronous data as well as specific low latency packets that can be transmitted with a highest priority.
In addition, some specific chapter 11 (roughly equivalent to chapter 10) data can also be broadcast, allowing transport of a large set of additional data usually stored and managed by on-board recorders (analog, serial, audio, video….).
Chapter 10 format is now widely used as a telemetry data transport protocol used by a large set of equipment such as RF receivers, data processing systems.

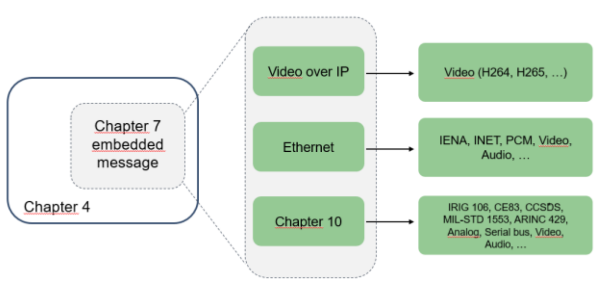

Figure 2 - Chapter 7 data management

On-Ground, the system in charge of Chapter 7 data decoding must propose a large set of de-commutation capabilities and must act as a gateway to reproduce on-board system raw data flows. This leads to specific challenges for Data Processing Software.

This document deals with general software concepts introduced to efficiently manage Chapter 7 data on ground in Nexeya MAGALI Data Processing System.

These concepts are illustrated by their successful implementation in the SAFRAN AIRCRAFT ENGINES “engine” test campaign, where Magali software runs on a Telemetry Ground system, in charge of acquiring, de-commutating and displaying of telemetry data in respect of the IRIG 106 chapter 7 standard.

2. A practical case: Engine flight test campaign

SAFRAN AIRCRAFT ENGINE started a new “engine” flight test program in 2014.
This campaign was located in San Antonio (Texas, USA) in a former SAFRAN US site and has recently moved to Istres (south of France). The campaign based on specifically equipped flying bench is still on going.
During this campaign, the on-board and ground architectures evolved from a classic chapter 4 architecture to a chapter 7 based system.
As an essential brick of the ground architecture, Magali chapter 7 Data Processing ¨Software is an example of the contribution of the chapter 7 format on a test campaign.

Context:

Test of engine and related equipment require the acquisition of approximatively 600 sensors (pressures, temperatures, vibrations…), up to 800 ARINC 429 parameters and mission audio.

The original test campaign was based on a Chapter 4 PCM using PCM-FM modulation in S-band.
The main data processing software is SAFRAN “in-house” software (MISTRAL). It is perfectly adapted to the specific needs of the campaign in term of data visualization processing and storage.
MISTRAL is used by flight test engineers on-board and receives all data in IENA format directly from on-board switch.

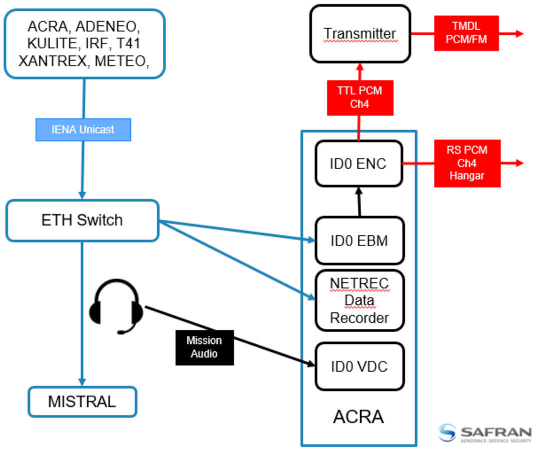

Figure 3 - On board chapter 4 architecture

On board, the system is mainly based on:
- Data acquisition modules,
- IENA gateway (for transmission of the data to MISTRAL)
- Analog audio acquisition module (for mission audio)
- Chapter 4 encoder and transmitter in charge of transmission of IRIG 106 chapter 4 PCM frame to the ground.

The PCM frame is finally embedding:
- Analog data
- ARING 429 data
- Mission audio

MISTRAL software is also used on the ground, in the control room.

On the ground, chapter 4 telemetry stream is received, demodulated and processed by Magali DPS.
Magali is dedicated to:
- Acquisition and display of telemetry data provided by RF Receiver through an IP link.
- Audio extraction from chapter 4 and direct rendering through audio jack
- Reconstruction of IENA frames to feed MISTRAL.
- Antenna slaving (using aircraft TSPI via the telemetry link) through and RS232 link

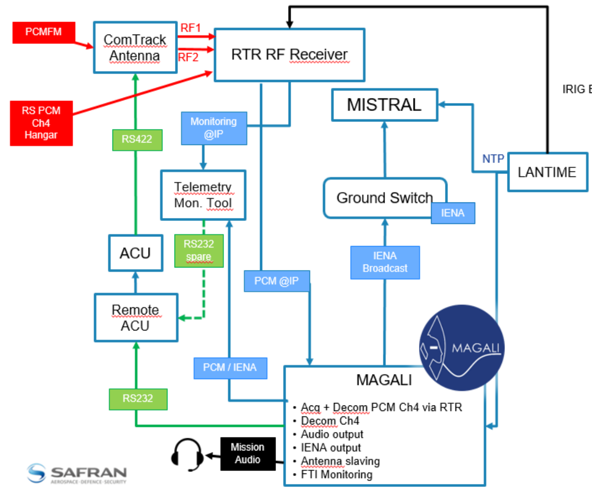

Figure 4 - Ground chapter 4 architecture

Drawbacks:

Various disadvantages have been identified with this original architecture among which the **limited bandwidth (1.0 Mbps)** which added constraints to the set-up.
The setup of the frame in telemetry encoder was not easy for several reasons.

First, a large part of the necessary information was coming from ARINC 429, asynchronous data. This implies a provision of allocated positions in the frame that has to be filled even if no ARINC message is transmitted. In this case, the strategy of the encoder is to repeat the last acquired values in the frame and therefore feed the frame with non-useful redundant information. As a consequence PCM frame relevant data was only providing 60 to 80 % of the Chapter 4 grid.

The bandwidth limitation and the size of the PCM frame implies a down sampling of on-board sensor data (reduction from 32 Hz to 8Hz) and thus a different setup of MISTRAL on board and On-Ground.

Because of very tight configuration possibilities, each type of test (focus on specific parameters) was implying a new setup of on-board equipment but also on the ground. For information, the complete test campaign was composed of approximatively 18 different trials with all configuration management difficulties (test setup on board and ground, sensor database etc…) to retrieve test environment in a later post processing analysis.

In addition, SAFRAN faced compatibility issues with on-board acquisition module and encoders. Addition of new functions was very difficult as legacy equipment was not compatible with the newest hardware and software.

Finally, because of all these limitations, MISTRAL had to be configured (IENA based data) differently on board and on the ground.

In front of all these difficulties, SAFRAN invested on a new architecture based on acquisition of Chapter 7 compatible equipment and a renewal of part of their legacy installation where MAGALI Data Processing System was used in several scenarios.

A new architecture based on Chapter 7 15 (full IP) telemetry downlink

The first trials around this new architecture started with laboratory setup in mid-2019. The first flight tests occurred in July 2020.

The main update was to extend the bandwidth of the system to 2.3Mbps. This improvement was mainly done by a change to SOQPSK modulation and upgrade of receivers for this modulation scheme.
The choice of Chapter 7 compatible equipment was quite trivial and highly related to the necessity to transmit asynchronous data. It was also the opportunity for SAFRAN to add new features such a High definition video acquisition.

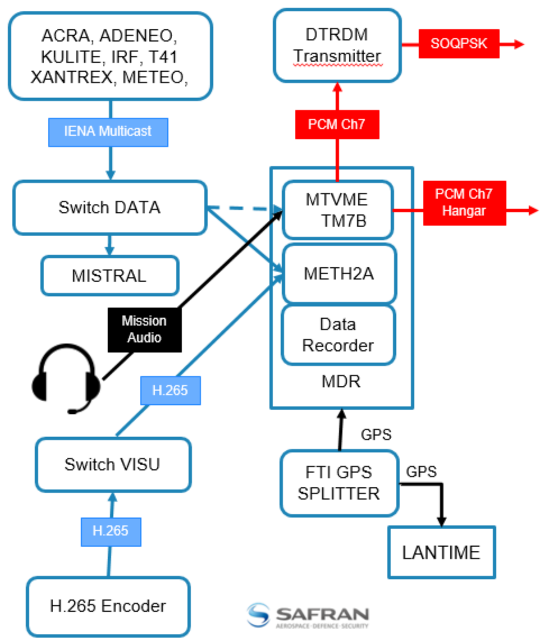

Figure 5 - Ch7 On-board architecture

The On-Board system is now based on a Chapter 7 compatible On-board recorder from SAFRAN DATA SYSTEM: the MDR.
This recorder is acting as a Chapter 7 – 2015 gateway (i.e. the frame is full Chapter 7, with no chapter 4 data) in charge of:

- Video (Raw H265 RTSP – Raw Ethernet packets of CH7)
- IENA (Raw Ethernet packets of CH7)
- Transmission of GPS data and MDR system status as serial packets in CH11 packets
- Acquisition and transmission of Mission Audio in CH11 packets
- PTP v2 time server for the synchronization of all the systems
- Telemetry chapter 7 PCM output

The on-board architecture is highly simplified.
All ARINC information and sensor data are now formatted in IENA (by the sensor directly or through specific converter modules). IENA Ethernet data are provided directly to MISTRAL and to MDR.
MDR is in charge of chapter 7 packing and transmission of the PCM to on-board transmitter.

On the Ground, the RF telemetry receiver is updated to support SOQPSK modulation.
A GMDR (Ground MDR) is also introduced, acting as:

- Chapter 7 Gateway, able to reproduce on the ground the On-Board Video and IENA Streams and Mission audio.
- Chapter 10 recorder
- Chapter 10 UDP transmitter

MISTRAL is finally connected directly to GMDR IENA stream.
MAGALI DPS is also an essential part of this setup and is used in various scenarios that will be described later in this paper.

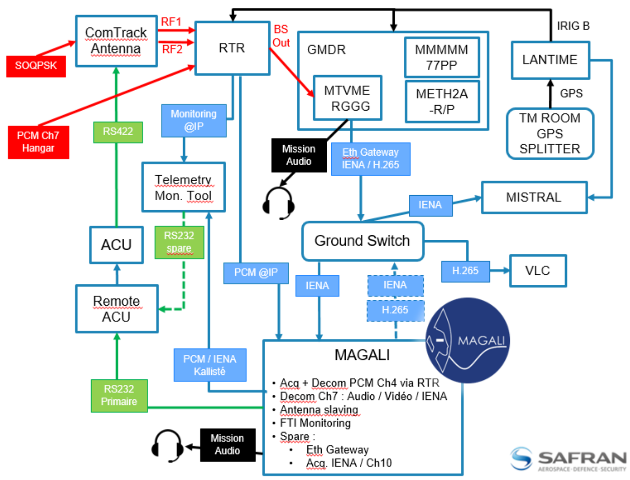

Figure 6 - Ch7 Ground architecture

No more bandwidth limitation:

All necessary information from ARINC 429, asynchronous data can be placed in the frame with no specific care of the IRIG 106 chapter 4 frame definition. Down-sampling of sensor data is not necessary anymore (32 Hz sampling rate is now possible) and a same setup of MISTRAL software can be populated on the Ground.
The chapter 7 frame is 100 % fed with useful data.

In addition, a specific Ground mode allows to connect MDR to the RF Receiver directly when the aircraft is on ground, parked in a hangar, for pre-flight or telemetry system test.

A few drawbacks:

The system cannot be connected to the PCM and the network at the same time: IENA on-board and PCM CH7 IENA from board are identical: There is no way to differentiate Ethernet packets (impossible to configure). Sources must be selected manually.

3. Challenges of Chapter 7 compatibility for Data Processing Software:

MAGALI DPS has evolved as the emergence of Chapter 7 and as an essential part of this new Architecture, NEXEYA accompanied SAFRAN in their flight test installation renewal, facing new challenges.

The main objectives in the integration of Chapter 7 data processing in Magali were:
- The management of a large set of different data and protocols with a good level of performance
- The tolerance to bit errors in the transmission
- The Multi-source time synchronization
- Raw data storage and data gateway
- To provide a User friendly setup:
    - Keeping the same ergonomic and principles
    - Provide an easy and automatic configuration
    - Possibility to Import of test configurations from ground setup directly

Tolerance to bit errors:

Due to air transmission of telemetry packets, bits errors are quite frequent. It is possible to add parity errors checking or classic checksum control of the main chapter 4 frame. However, raw Ethernet packets transmitted on ground have no specific error management except IPv4 protocol checksum.

It is the case of Ethernet protocols:
IENA is a good example. This Ethernet based protocol is supposed to be bit error free and does not include any error code protection. Errors occurring on data payload do not require specific attention by the software treatment (i.e. data in error are treated without any specific management, simply providing bad measurement of false results) a specific care has to be provided on the management of datation filed errors. In IENA, time information is located inside the data just before data payload. Any errors in the transmission may produce bad time decoding and spurious time jump issues.
To prevent this phenomena the data processing software must propose an alternative to ignore internal time and use a different timestamping strategy. The safest solution is to use local time available on ground (through for example IRIG B time input of receivers or frame synchronization hardware).

The same kind of spurious effect can be observed on Chapter 7 raw Ethernet video packets. Because of bit errors on the video, the rendering of the video can be disturbed and display a lot of image artefacts. A very bad quality can have even worst effects: the video player of Data Processing Software can be seriously disturbed leading to random software issues that must be carefully treated to prevent a crash of the system.
As a general comment, incorporating forward error correction to the telemetry link would be ideal to prevent such a scenario, but this is not always possible. As an alternative, some specific video quality management algorithms must be activated at a very low level of video decoding libraries. The safer strategy is to simply cancel complete images if detected with a bad quality (after a checksum verification for example).

This software protection must also be applied to other types of data de-commutation modules related to protocols without dedicated error management (Ethernet protocols, serial data, avionic buses…) and will not be detailed in this paper.

Some tolerance to errors strategy has been introduced in Chapter 7 protocol for the management of Chapter 11 data.
A part of chapter 11 headers is encrypted with a specific error code management (Golay codes).

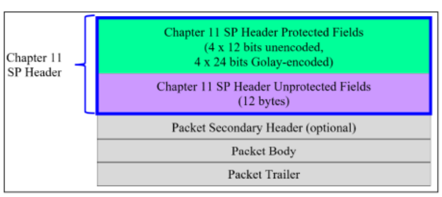

Figure 7 - Chapter 11 Headers – Golay code management

This strategy secures the data reception quality and rejection of bad Chapter 11 packets. This treatment implies a very resource consuming verification of Golay code by DPS on ground to validate the header. Some processing resources are also necessary to reconstruct a Chapter 10 compatible header.

Chapter 10 Headers must be rebuilt for two reasons:

- Keep the compatibility with Chapter 10 de-commutation module
- To broadcast chapter 10 files through UDP stream (acting as a gateway).
- To store chapter 10 files locally for later post processing (as a recorder) or data replay (as simulator)

In case of error, the whole packet is lost.

If some errors occur in the unprotected field, the software relies on chapter 10 packet checksum verification. In order to improve time stamping management, an option has been introduced in MAGALI DPS. The user can bypass the embedded time information in the chapter 10 and use the on-ground local time provided by Chapter 4 equipment (IRIG B for example).
Ch10 packets are then time-stamped using a local reference time. The ch10 RTC 48 Mhz counter is correlated with a local date synchronization reference.

Resource consumption:

In addition to Golay code decoding and multi source management, low-latency packets can be sent in the middle of a payload (for example large video data that needs several frames).
A Double treatment has to be performed in parallel:

- To manage on going packets
- To manage low latency

This has a strong impact on the performance of the system performance.

Raw data storage and UDP broadcast:

As a first priority, incoming chapter 7 frames are stored in a raw format from the source (TM over IP stream provided from RF Receiver). This data can be used for later formatting, for example in case of error in test configuration (wrong parameter extraction or conversion…)

Each CH7 embedded Ethernet stream (Raw Ethernet packets) is also packed in a specific storage file so that user can retrieve after flight a raw video file or a raw specific file.
All stored raw packets are also broadcasted in UDP so that system can be used as a real time Chapter 7 to IP gateway.

In addition, Chapter 10 UDP stream is also provided in real time by adding UDP IRIG 106 headers on top of chapter 11 packets. This transforms the system into a chapter 10 gateway able to feed any Chapter 10 compatible equipment. Of course these packets are also stored on disk as chapter 10 files.

This additional storage and gateway functionality is useful for later post processing or in replay scenarios (using specific software tools).
It is also a perfect spare solution in case of failure of related equipment (recorder, gateway…).

Setup and configuration:

Chapter 7 frames are embedded in a main Chapter 4 frame. Within chapter 7, in addition to Ethernet raw data that can be used to transport different types of data (video, IENA, INET…), chapter 10 packets may also include a large variety of different sources (Analog, Digital, Serial, Digital buses sur as ARINC 429 or MIL1553, Audio, video…). This large number of possibilities greatly simplifies the architectures of on-board systems but defers the difficulty of the treatments to the ground.
Any type of the data mentioned above have to be configured specifically with a large set of different options (list of parameters, position in the frame, message definition…).

Obviously the best way to present all this information to users is a tree diagram as in the example below:

Chapter 4 main frame
    Chapter 7 embedded frame
        Chapter 11 packets
            Analog data
            Serial data
    CH7 video stream
    CH7 IENA stream

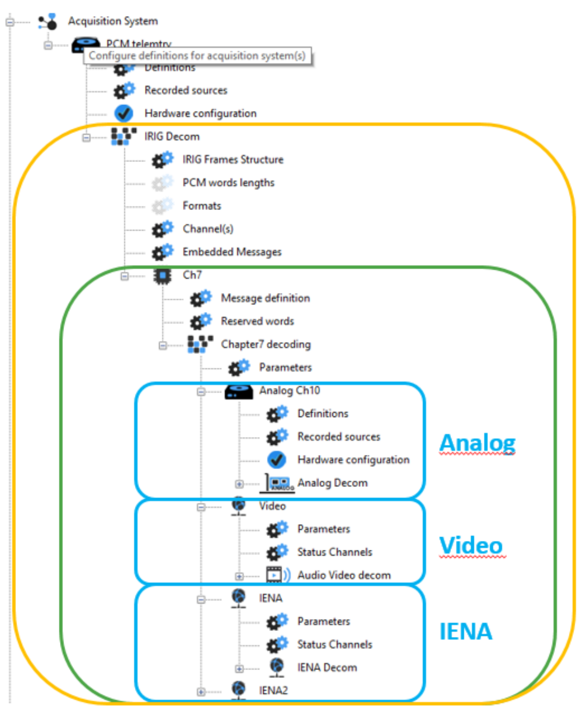

Figure 8 - MAGALI setup tree interface

In order to ease the construction of this setup tree an automatic detection and analysis of all chapter 7 contents is mandatory.
The challenge is to be able to perform such a detection in a preparation stage.

This automatic configuration requires an access to the data itself. If this is not always possible in front of installation setup (data simulator, availability of aircraft…) the setup is often performed "in lab" or reusing on board Chapter 10 recording of Ch7 data.
This type of encapsulation adds another level in the preparation tree and increase the complexity of the setup.

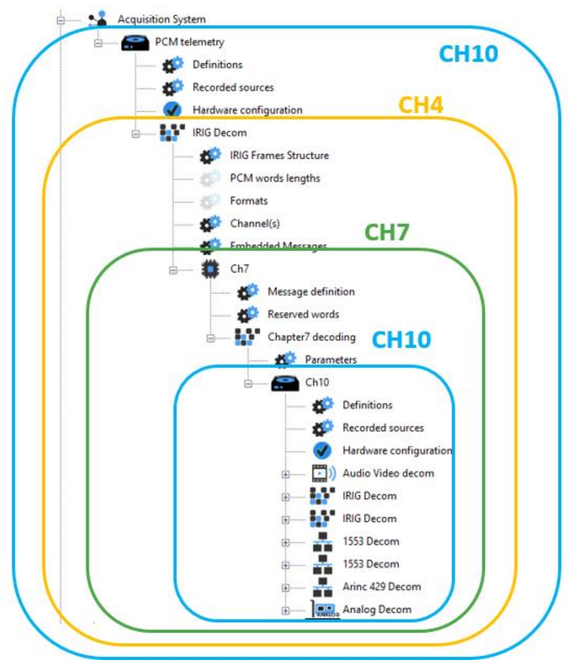

Figure 9 - Chapter 7 data in a chapter 10 file record

In order to simplify the process, the best way to present this information to users is to identify all sources:

- Raw Ethernet packets (related to the capture of video, IENA or INET data on board).
- Chapter 11 packets.
- All data types available in chapter 10

The DPS must then propose a packet sniffer interface, providing the list of available data types and sources.

The different raw Ethernet packets can be generated on board by several acquisition systems. The user interface must show relevant information such as source and destination IP addresses, type of connections (UDP/TCP…), UDP ports,..

The different data available in a chapter 10 flow can also be shown with their related ID and type (Audio, video, analog data)…

The user can then simply select a subset of data types and the software creates a configuration corresponding to user choice. Each selected source is added to the tree as an independent node and can be configured separately.

The configuration of each node can then be edited manually or by recovery of the on-board configuration.
Specific configuration import modules can be added to the software (depending on on-board equipment provider) or using TMATS file analysis in case of chapter 10.

Below (figure 5 and 6) is the Magali automatic setup user interface. It shows the list of available sources and user can build a specific configuration, focus on its needs.
A setup node is then created for each data source (CH10 packet or Ethernet packet) and the corresponding Decom module is proposed.

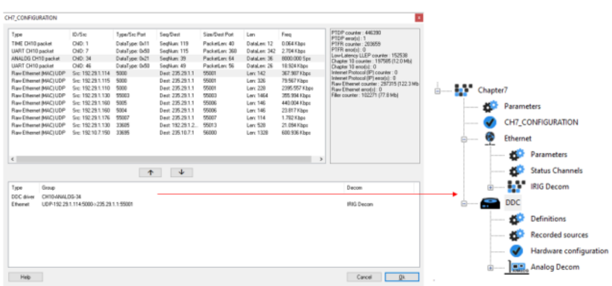

Figure 10 - automatic detection of chapter 10 packets

In addition, it is also a great help for the very first trial to propose data content analysis tools (chapter 10 bloc analysis, automatic IENA packet detection…)

4. MAGALI Data Processing System, at the heart of the ground system:

Thanks to a wide set of hardware and protocol compatibility, MAGALI Data Processing System has been used by SAFRAN in various test scenarios:

- Acquisition of chapter 7 stream via RTR IP stream
- De-commutation of Chapter 7 data: Audio, Video H264 and IENA
- De-commutation and display of Chapter 7 video H265
- Direct playback of chapter 10 audio packets (and reproduction through a jack connector)
- Antenna slaving
- FTI data monitoring
- Post processing of on-board recorder chapter 10 files

MAGALI station has also be used as a spare gateway system during a failure of GMDR.

MAGALI Data Processing System also simplify the setup on the ground thanks to

- Chapter 7 configuration wizard with easy selection of available sources
- Possibility to import ground equipment setup (excel files or specific such as xml)
- Analysis of TMATS companion file for chapter 10 stream definition
- If no TMATS available analysis of received packet for an auto-detection of the sources

Audio Jack output of GMDR cannot be connected to the sound mixing system of the control room due to the distance. It is then possible to go through CH10 audio broadcasted to MAGALI stations located in the control room and connect the sound mixing system of the control room directly to the jack connector of the MAGALI station).

5. Conclusion

As a conclusion, Chapter 7 simplifies on board and ground architectures. It also reduces the time dedicated to mission set-up. It is therefore perfectly adapted to the transport of asynchronous data (video, digital buses…) mixed with a set of synchronous data (analog data).
Its compatibility with large set of legacy systems is also a big advantage (TM transmitters, receivers and bit synchronizer). Its integration in Data Processing

Softwares also includes a large set of new uses cases and possibilities such as data gateways, spare solutions…

Chapter 7 is a future proof format, and is the perfect transition from past architectures to the future of telemetry where full IP standard will most likely take the lead.

6. Acknowledgements

Sabine LASSERRE NEXEYA, Marketing & Quality
Gerald ESCRIVA Safran Aircraft Engines, Flight test department manager
Jerome VIRON Safran Aircraft Engines, Flight test engineer
Special thanks to:
Kip Temple Air Force Flight Test Center, Edwards AFB CA

7. References

[1] IENA-FORMAT_RP0701637_v5.0
[2] Telemetry Standards, RCC Standard 106-19

8. Glossary

DPS: Data Processing Software/System

PCM: Pulse Coded Modulation

TSPI: Time Space Position Information