

Model-Based Interface Management for Flight Test Instrumentation Systems

Claudia Pérez Rus¹, Sergio Garrido Pintado², Stéphane Le Gal¹

¹ *Airbus Defence and Space, Avenida del Aeropuerto, s/n, 41020 – Sevilla, Spain*

² *Airbus Defence and Space, Calle Aviocar, 2, 28906 – Getafe, Madrid, Spain*

claudia.perez.rus@airbus.com

sergio.garrido-pintado@airbus.com

stephane.le-gal@airbus.com

Abstract

Model-Based System Engineering (MBSE) approaches are significantly improving systems visibility, consistency and collaboration across multidisciplinary teams. Nevertheless, it is a highly structured methodology, which is challenging when applied to systems that demand flexibility, rapid iteration and frequent reconfiguration, which is the case of Flight Test Instrumentation (FTI) systems. This is explored in previous research that tailors MBSE methodologies to FTI systems. This paper goes one step beyond. An important phase in the FTI development process is the management of interfaces between FTI equipment, and towards other aircraft systems. Once FTI system architecture model is mature, the subsequent interfaces are defined in detail and linked to the required flight test parameters. There are multiple heterogeneous interface definitions that must remain fully traceable to the architecture model to ensure consistency, minimize integration risk, and maintain system visibility throughout development cycles. This paper explores the challenges of a complete model-based FTI definition and proposes a structured approach to bridge the gap between model-based methodologies and FTI specific definition needs, focusing on linking MBSE architectural artifacts with interfaces and flight test parameters management in a unified digital environment

Key words: MBSE, FTI, electrical interface, functional interface, prototype

1. Introduction

Model-Based System Engineering (MBSE) approaches are significantly improving systems visibility, consistency and collaboration across multidisciplinary teams. Despite its benefits, MBSE is a highly structured methodology, which is challenging when applied to systems that demand flexibility, rapid iteration and frequent reconfiguration. This is the case of Flight Test Instrumentation (FTI) systems. In previous work [1], the application of tailored MBSE methodologies to FTI systems was investigated, concluding on the need to adapt modelling approaches to the particularities of FTI.

An important step in the FTI development process is the management of interfaces between FTI equipment, and towards other aircraft systems through a robust interface definition methodology, resulting in the establishment of reliable digital interface models and Interface Control Documents (ICDs). FTI architectures consider aircraft electrical ICDs - and be consistent with them at any point of time - to identify valid tapping points and types, connectors' availability, pin assignments, power constraints, etc. In parallel, FTI systems depend on aircraft functional ICDs, mapping the avionics data buses to be tapped, their structure and content, their communication protocol, and many other dependencies enabling the extraction, processing, formatting, synchronization

and distribution of aircraft data for real-time monitoring and post-flight analysis.

This paper starts with a FTI architecture model as its foundation and explores how electrical and functional ICDs for FTI systems are derived, integrated and controlled within a model-based framework.

1.1. State of the Art

This paper extends the studies presented in [1], which investigates the application of MBSE methodologies to prototype aircraft systems, focusing on the particularities of modelling FTI systems. Although the main challenges of applying MBSE methodologies to FTI systems are identified in [1], it only covers system architecture definition, but does not go into how further detail system description that is required to define flight test instrumentation. The work carried out in [2] describes model-based representation of interfaces using SysML. It emphasizes that interface engineering is a critical function of the discipline of system engineering. Bringing this methodology into an aerospace context, [3] presents the interface management of NASA projects that follows a model-based approach. The study presented in [4] examines the application of MBSE to aircraft certification processes, for which aircraft prototypes and FTI in particular are key contributors. Moreover, the work carried out in [5] explores how MBSE can facilitate and support a flight testing of prototypes. It does not address the FTI in particular, but serves as an

example of how MBSE can be applied to flight test environments. The previous literature does not cover the application of model-based interface management to flight test instrumentation system, which is the scope of this paper.

1.2. Objectives

The main objectives of this paper are

- analyzing the nature of FTI interfaces, considering both electrical and functional domains,
- comparing MBSE and traditional approaches for interface management in the context of FTI, assessing benefits and challenges,
- and finally, investigating how a MBSE approach can be applied to the management of FTI interfaces.

1.3. Structure

To meet the previously enumerated objectives, this article is structured as it follows:

- **Background:** The first sections provide a brief description of FTI systems, emphasizing the interface diversity. MBSE and traditional approaches are compared in the context of FTI interface management.
- **From Architecture Model to Interface Definitions:** This chapter describes the elements that are defined in the architecture and drive the interface definitions. Then, mapping to electrical and functional ICDs is detailed.
- **Proposed Framework:** This chapter provides a global view to integrate architecture and interfaces definition of FTI systems. It provides specific examples of interface management for FTI sensors, equipment or tapings in particular.
- **Conclusions and Future Lines of Study:** This concluding chapter collects future steps, lessons learnt and overall conclusions.

2. Flight Test Instrumentation System and Interface Diversity

Main purpose of a FTI system is to gather flight test data - in a safe and secure manner - which are later used for validation and certification purposes. Since FTI system only supports flight test campaigns, its installations are not intended to be permanent and are continuously adapted to evolving requirements.

The FTI operational requirements, together with the adaptation of this system to the evolution of the aircraft (different prototypes and flight test campaigns), makes the FTI system inherently complex and versatile. In particular, its architecture is highly dependent on factors such as the number and type of parameters being acquired and recorded, and the need of real-time telemetry transmission, or the platform's size and available space for FTI installation, among others.

In a general scenario, the FTI comprises acquisition, recording, time synchronization, data distribution, control, monitoring, telemetry and power distribution

subsystems. In addition, hundreds or even thousands of parameters with very diverse characteristics are acquired, ranging from Ethernet, ARINC429 or MIL1553 buses to discrete signals or analog sensor outputs. It is key to keep in mind that MBSE approaches are highly valuable when managing interfaces, but the highly dynamic and iterative nature of flight test is a big challenge for structured models.

For a better understanding, the FTI architecture can be divided into three different layers: functional interfaces (Section 2.1), physical interfaces (Section 2.2), and protocols (Section 2.3).

2.1. Functional Interface Diversity

FTI systems interact with a wide variety of data sources, resulting on many functional interfaces. These interfaces differ in terms of data type, communication mechanisms, directionality, constraints, dependency on aircraft configuration, etc. Thus, the functional interfaces are heterogeneous, requiring careful management. Fig. 1 shows in a graphical way this variety of interfaces, that are mainly described below:

FTI Tappings (1): Tappings are performed to extract data from existing aircraft data buses, being a primary function of FTI systems. These functional interfaces are inherently constrained by the characteristic of the bus being tapped, as FTI generally operates as a passive observer without modifying bus behavior. FTI tapings handle existing data structures that are typically defined in aircraft functional ICDs. Indeed, these ICDs may vary depending on the current aircraft configuration. As a result, FTI must accommodate multiple variants of the different interfaces.

FTI Sensorics acquisition (2): FTI systems also acquire data from sensors installed for dedicated purposes. These sensors provide measurements such as environmental conditions or structural loads. From a functional perspective, sensors acquisition involves the conversion of raw physical signals into usable digital parameters (e.g., signal conditioning, calibration, scaling, sampling, etc.). Unlike bus-based interfaces, these are fully defined within the FTI domain, which offers greater flexibility but also requires careful configuration to meet the requirements.

FTI Subsystems communication (3): Apart from the interfaces towards other aircraft systems or sensors, the FTI subsystems also exchange data to support acquisition, processing, recording, and transmission of data, under strict timing and synchronization constraints. These interfaces are fully within FTI landscape; however, their definition must remain consistent "upstream" (tapings, sensors) and "downstream" (offline or real-time analysis).

FTI Data transmission to ground (4): One of the main functions of the FTI system is the transmission of data to ground for real-time monitoring in the flight test ground stations. Data transmission interfaces are typically constrained by bandwidth and link budget. Usually, not all the data that is acquired can be transmitted in real-time; thus, data telemetry subsets and prioritization of parameters is required.

FTI Control/Configuration commands (5): FTI systems also include functional interfaces for control and configuration, enabling the modification of the system behavior during operation. These commands may originate from on-board test panels, or from ground-based control stations. Typical commands might include activation/deactivation of some equipment (e.g., cameras), modification of telemetry

message, etc. This variety of functional interfaces reinforces the importance of interface management approaches capable of maintaining traceability between aircraft architecture, FTI architecture, and final test data that is served for analysis. MBSE provides a framework to address these challenges that is promising, but also requires careful adaptation to FTI particularities.

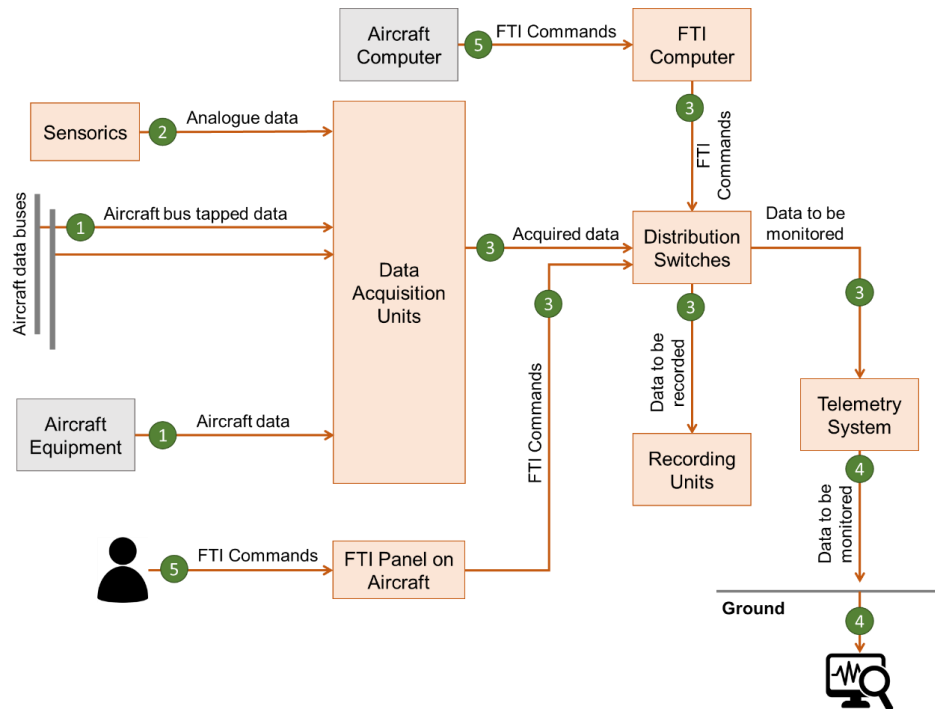


Fig. 1: FTI Functional Interface Diversity

2.2. Physical Interface Diversity

The functional interfaces must be supported by a physical layer (i.e., all required connectors, wirings and harnesses). This layer is also highly heterogeneous, not only due to the versatility of sensors types and their specific acquisition and conditioning methods, but also due to the varieties of tapping technics which may involve splices, direct connections, or the use of dedicated intermediate equipment.

All of this, together with the large number of parameters involved, further highlights the adaptability demand to the system and the need for tools answering FTI specific needs.

FTI Tappings: The previous section reflects that FTI tappings must not interfere with aircraft connections like data buses or power lines. This ensures system integrity, supports safety and certification aspects, and guarantees that the aircraft will behave as expected during the flight tests and throughout its lifecycle. In addition, FTI tappings have to be adapted not only to functional, but also to electrical interfaces and mechanical constraints (availability of connectors devoted for FTI, use of conditioners...) which may differ between serial aircraft and prototypes (see Section 3).

The three different ways to perform a FTI tapping are shown in Fig. 2: FTI Tappings:

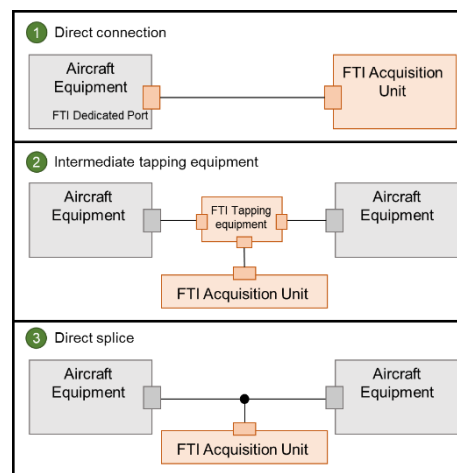


Fig. 2: FTI Tappings

Direct connection (1): a dedicated FTI connector or port is available in the corresponding aircraft equipment.

Intermediate tapping equipment (2): this element is part of the FTI system and represents a coupler for Ethernet or MIL-1553 buses tappings, for example.

Direct splice (3): for less sensitive buses like ARINC 429 or serial buses, and for other connections like a voltage tapping, a splice to the original connection can be done.

FTI Sensorics Acquisition: Sensors do not interact directly with other aircraft systems at an electrical or functional level. At physical level, they can be considered as a direct connection from the sensor to the FTI acquisition unit, or as a direct connection from the sensor to a conditioner and from the conditioner to the acquisition unit.

Other FTI Interfaces: The other interfaces detailed in Section 2.1 – such as communication subsystem, data transmission to ground and configuration commands – do not present specific features for FTI, and their physical connections can be treated in the same way as the rest of the aircraft.

2.3. FTI Protocols

FTI systems manage a high variety of communication protocols. This is mainly due to the fact that FTI systems have the role of an observer within the aircraft and acquire diverse types of data. Network-centric architecture may rely on Ethernet-based protocols with full-duplex and massive bandwidth capabilities, versus mission or armament systems, which are based on highly reliable, deterministic and immune to collisions buses as MIL-STD-1553, ARINC 429, CAN,

or serial buses, but with reduced bandwidth [6]. This becomes a technical challenge when acquiring and processing the data: some communication buses may operate at very high velocities or data rates, or with specific timing constraints, synchronization requirements, or proprietary implementation.

3. Prototype Configuration: Variants, Applicability and Effectivity

FTI systems must manage not only interface diversity and complexity, but also continuous configuration evolution. As highlighted in [1], *prototypes evolve in parallel to the serial system and both architectures must be synchronized to ensure robust configuration control*. Model-based environments must manage variants, applicability and effectivity; otherwise, MBSE application to FTI systems would be limited.

When an aircraft is being developed, its prototype (together with the FTI that will be installed) is designed in parallel as well. Consequently, it is important that MBSE tools accommodate the prototype as a variant: FTI particularities must be incorporated. There are not only inherent differences between serial aircrafts and prototypes, but also future deviations between flight test campaigns, etc. Fig. 3 exemplifies how the tools should accommodate specific prototype configurations together with serial aircraft.

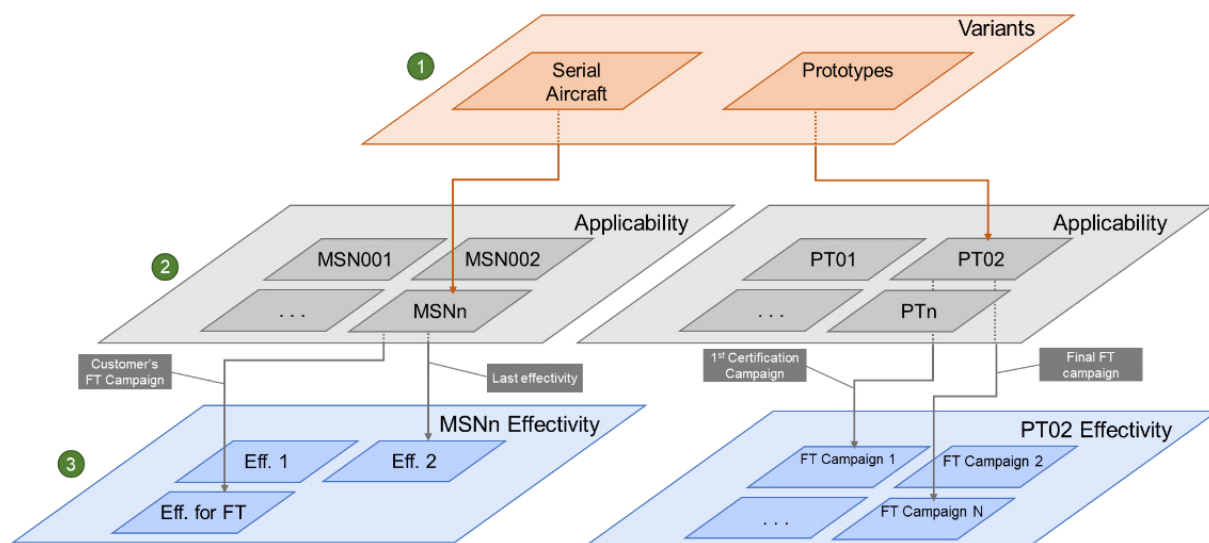


Fig. 3: Variants, applicability and effectivity

Variants (1): Serial and prototype aircrafts are represented in Fig. 3 as parallel variants that are inherently related one to each other. Thus, both variants must remain interconnected in model-based approaches.

Applicability (2): The different prototypes and serial aircrafts will also differ – in general terms – from one to another.

Effectivity (3): On top of that, one single prototype can have different configurations at different points of time (e.g., for different flight test campaigns), or even serial aircraft may need specific flight test instrumentation at some point for specific developments.

The management of variants, applicability and effectivity is valuable when modelling the interfaces described in Section 2. Beyond enabling traceability between prototype and serial configurations, it allows the representation of physical differences between individual prototypes. For instance, a specific tapping may be required for data acquisition on one prototype, whereas on another, only a provision (interface allocation) for future campaigns may be necessary. Fig. 4 shows an example for a splice.

Summing up, a model-based environment suitable for FTI interface definition must be capable of representing multiple prototype configuration, maintaining traceability to evolving architectures.

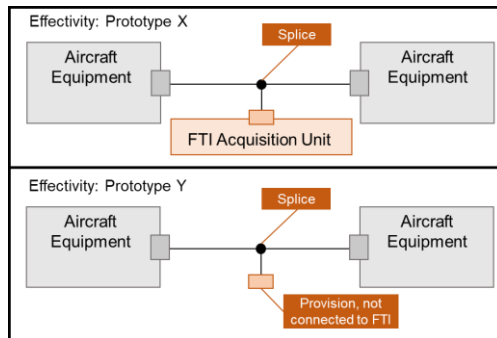


Fig. 4: Different FTI effectivity on prototypes

4. Model Based System Engineering versus other Traditional Practices

As emphasized in the previous sections, the huge diversity of electrical and functional medias challenges the establishment and maintenance of the whole system interfaces. On this regard, the use of MBSE may provide some opportunities but also some difficulties, which are gathered in Tab 1.

Functional interfaces: In traditional system engineering, definition of these interfaces is usually responsibility of each sub-system without systematic coordination at system level, and without a common

digital data base. This data is manually entered into FTI configuration tools, and the availability to FTI is usually at late stages. In a model – based environment, FTI is embedded directly into a standardized, common database alongside all systems, so a single source of truth is established. Furthermore, integrating FTI into the end-to-end definition at the earliest project stage provides all systems with immediate awareness of FTI requirements, allowing engineers to pre-allocate network bandwidth, space, and power while enabling seamless data stream validation during early integration rig testing.

Electrical interfaces: Traditional methods rely heavily on static documentation to define electrical interfaces. On the other hand, MBSE makes use of shared, common databases to establish a unified system model. This transition presents significant opportunities, as it allows the FTI electrical definition to be digitally traced both to the high level FTI architecture and to the other aircraft systems. However, implementing this methodology introduces unique difficulties: the rigid robustness required to maintain model-based processes often stands in direct contradiction to the high degree of flexibility that FTI demands, especially during testing phases.

Tab 1: Opportunities and difficulties of applying MBSE to FTI interface management

	Traditional system engineering	Model - based system engineering	
Functional ICD	Isolated functional definition for the different aircraft systems, lack system-level coordination and require manual entry into FTI tools at late stages.	FTI is embedded into a standardized, common database from the earliest stages as a single source of truth.	Opportunities
			Functional ICDs from the tapings performed can be directly consumed by FTI tools, so that the functional descriptions are unified from early stages.
			Difficulties
Electrical ICD	Electrical definition based on documentation	Electrical definition based on shared and common databases	Early, strict end-to-end functional alignment can restrict the agility needed to modify FTI functional descriptions. Customization of MBSE processes is required to cope with these FTI particularities.
			Opportunities
			FTI electrical definition is digitally traced to FTI architecture, and to the electrical definition of other aircraft systems.
			Difficulties
			The robustness of the model-based processes is in contradiction to the flexibility required for FTI definitions.

5. From Architecture Model to Interface Definitions

This paper continues the work started in [1]; thus, its starting point is a FTI architecture model. This architecture model captures FTI system from requirements to technical decomposition and definition, going through functional architecture as well. Anyhow, as stated in [1], “[...] *further assets* (beyond system architecture model) *are required for the complete definition of the FTI, from detailed measurement chain definition, pin-to-pin design, etc.*”. Indeed, this chapter provides the transition from FTI architecture model to detailed functional and electrical interface descriptions.

5.1. Model Elements Driving ICDs

The following Fig. 5 and Fig. 6 provide the key model elements that are considered as a starting point or reference to drive the detailed interface descriptions. Fig. 5 shows the typical model elements found in technical architecture models (blocks, connectors and ports). Fig. 6 shows the typical model elements found in functional architecture models (functional flows).

- **Blocks** establish the boundaries across which interfaces exist. Fig. 5 shows: interactions between FTI and Flight Control System or Communication System, interfaces between different FTI equipment, and interfaces with external actors (Air Traffic Controller and Flight Test Engineer).

- **Ports and connectors** define interaction points and relationships between blocks. These elements define: physical interactions (Fig. 5), and functional interactions (Fig. 6).
- **Functional flows** define how and which data circulates through the system. As shown in Fig. 6,

these elements are important to identify which interfaces are required and how they should be defined.

These are the elements from the architecture that will be refined further into electrical ICDs (see Section 5.2) and functional ICDs (see Section 5.3).

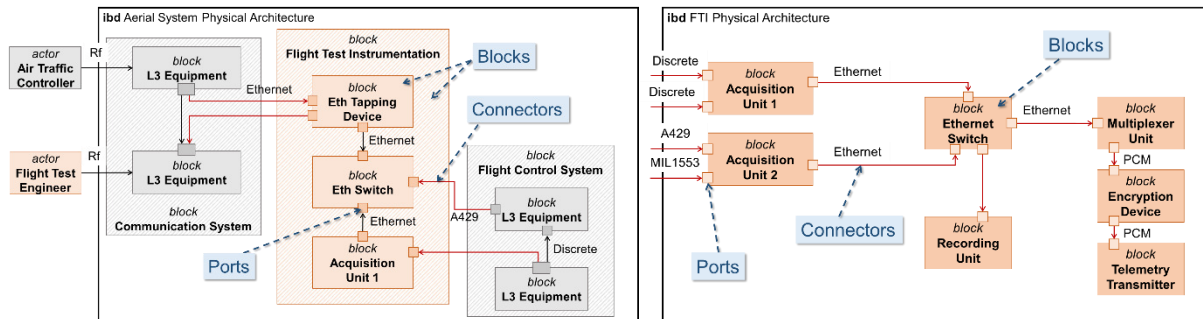


Fig. 5: FTI architecture model – some examples of technical view (based on [1])

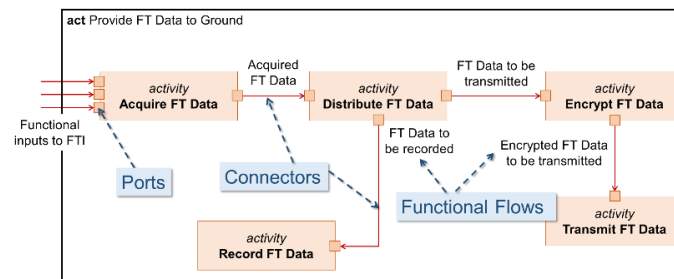


Fig. 6: FTI architecture model – an example of functional view (based on [1])

5.2. Mapping FTI System Architecture Interfaces to Electrical ICDs

The architecture model can be extended beyond the high-level system representation to include detailed electrical interface definitions, capturing the content traditionally implemented in electrical ICDs. By introducing connectors, pins wiring relationships and

electrical characteristics within a model-based environment, the electrical definition becomes directly linked to the architectural elements that drive it.

Blocks, ports and connectors can be traced down to their electrical realization (see Tab 2). Fig. 7 depicts this mapping from FTI architecture to electrical interface definition.

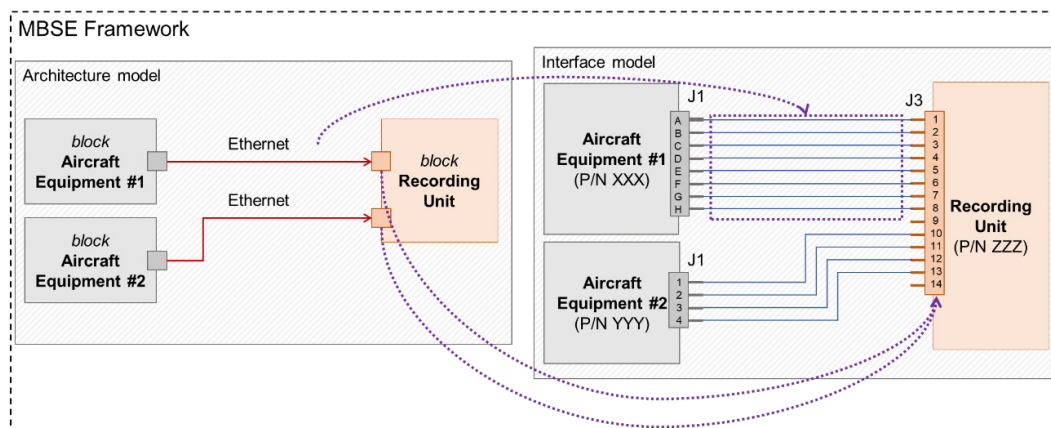


Fig. 7: Electrical traceability between architecture and interface models

Anyhow, while traceability between architecture and interface definition is a well-known benefit of MBSE, its application to FTI systems presents additional challenges. Recapping from previous sections, FTI

interfaces are largely derived from external aircraft definitions. In addition, FTI systems are highly dynamic, with frequent changes and configurations across aircrafts and campaigns. This variability makes

it very difficult to maintain consistent traceability. As a result, traceability becomes both more valuable but more demanding for FTI. On the one hand, it enables identification of impacts across architecture and electrical definition, reducing integration risks. On the other hand, it requires modelling approaches capable of handling multiple configuration baselines and continuously evolving system definitions. FTI systems can be seen as a stress-test for MBSE methodologies, exposing both their strengths in managing complexity and their limitations when applied to highly flexible environments.

5.3. Mapping FTI Parameters and Aircraft System Architecture to Functional ICDs

In an analogous way, architecture models can be extended to include detailed functional interface definitions. Tab 2 gathers how the system architecture elements are refined into functional descriptions.

This is particularly valuable when doing a tapping of a bus on aircraft: that architecture definition would be unequivocally linked to a functional ICD. Thus, this is a key input for FTI equipment configuration and programming, ensuring the successful extraction of data of the buses being tapped for real-time or offline monitoring. Fig. 9 shows how the architecture modelling is refined into functional definition.

However, FTI integration into the models is not straightforward, as explained in detail in following Section 6

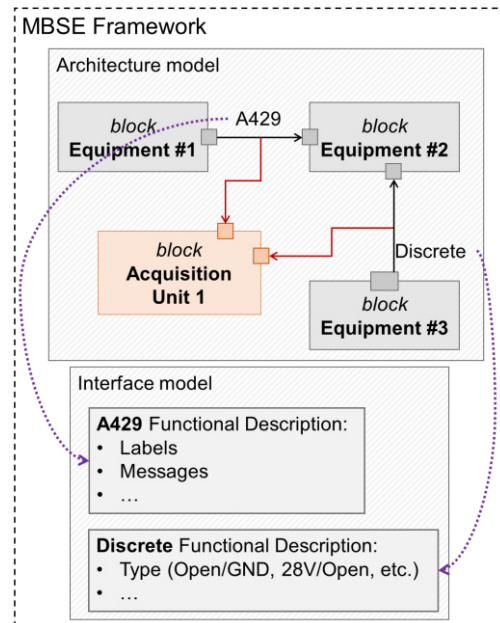


Fig. 8: Functional traceability between architecture and interface models

Tab 2: System architecture elements mapping to electrical and functional elements

System. architecture	Electrical ICD	Functional ICD
Blocks	Equipment	Equipment
Ports	Equipment connectors, ...	Source/Destination
Connectors	Pin mapping, harness and wiring properties, ...	Data flow, exchange type, ...
Functional flows	Physical layers, bus characteristics and constraints, ...	Protocols, messages, ...

6. Proposed Framework

This section addresses the general application of the relationship between the architecture and interface models to the FTI. First, the main characteristics of electrical and functional information are refined in detail; secondly, the actual interaction between both models is described across the variety of FTI scenarios (FTI subsystems communications, FTI tapings, and FTI sensorics) using concrete

examples; finally, it describes how all this information is crucial for the optimal operation of the FTI and the accurate analysis of flight test data.

Fig. 9 illustrates how the aircraft architecture model is progressively refined into interface definitions – both electrical and functional. A very simplified view is shown, where architecture elements are translated into functional and electrical interface models.

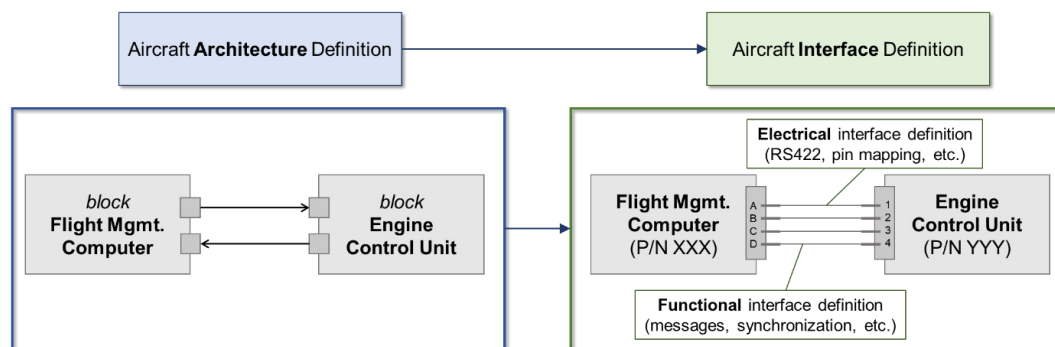


Fig. 9: Aircraft architecture definition refinement into aircraft interface definition

However, the integration of FTI systems into this framework is not straightforward due to its intrinsic particularities:

- FTI systems are, typically, only present in prototype or development aircrafts.
- FTI systems are temporary and highly variable, which is often in contradiction with the robustness of the model-based approaches.
- FTI consumes information from aircraft interfaces. For example, the functional ICDs of the buses that are tapped are required to post-process the bus data and support flight test analysis activities.
- FTI systems usually present campaign-specific instrumentation variants and evolving acquisition needs.
- FTI operation relies on critical technical parameters such as measurement identifiers, sensorics and bus tapings measurement chain definitions, the configuration of acquisition cards and channels, etc.

Summing up, FTI systems introduce additional complexities not present in standard aircraft development flows. If FTI particularities are not integrated into the model-based framework at early stages, MBSE would bring only partial value for FTI development: the critical details required for instrumentation definition would remain disconnected from the models. Integrating these specific FTI artefacts is essential to achieve end-to-end consistency throughout FTI definition and lifecycle.

In Fig. 10, the different FTI definition steps are drawn on top of Fig. 9.

FTI Requirements (1): The different systems and disciplines declare their specific flight test instrumentation requirements. These usually gather the required tapings and sensorics, together with other requests (cameras, GPS signals, etc.).

Based on these requirements, the FTI architecture is defined. As explained in Section 2, it can be divided into FTI subsystems architecture (also known as FTI Core), tapings and sensorics.

FTI Subsystems Architecture Definition (2): The definition of the FTI core architecture comprises the main equipment to fulfill FTI functionalities (acquisition units, recorders, telemetry devices, distribution switches, etc). As explained in [1], this architecture is modelled in parallel with the general aircraft architecture, in the same way as other aircraft systems, but in a much shorter process and requiring several interactions with the other systems. Then, the architecture is refined at both the electrical and functional levels to achieve the required level of details. An example of this is illustrated by the connection between the FTI Acquisition Unit and the FTI Time Master Switch in Fig. 11 (see 1 in the figure). The left side displays the connection between both components within the architecture model, which feeds the electrical and functional interface model down to the specific detail (in this case) of an Ethernet connection and the message's functional ICD, as shown on the right side of Fig. 11 (see 1 in the figure).

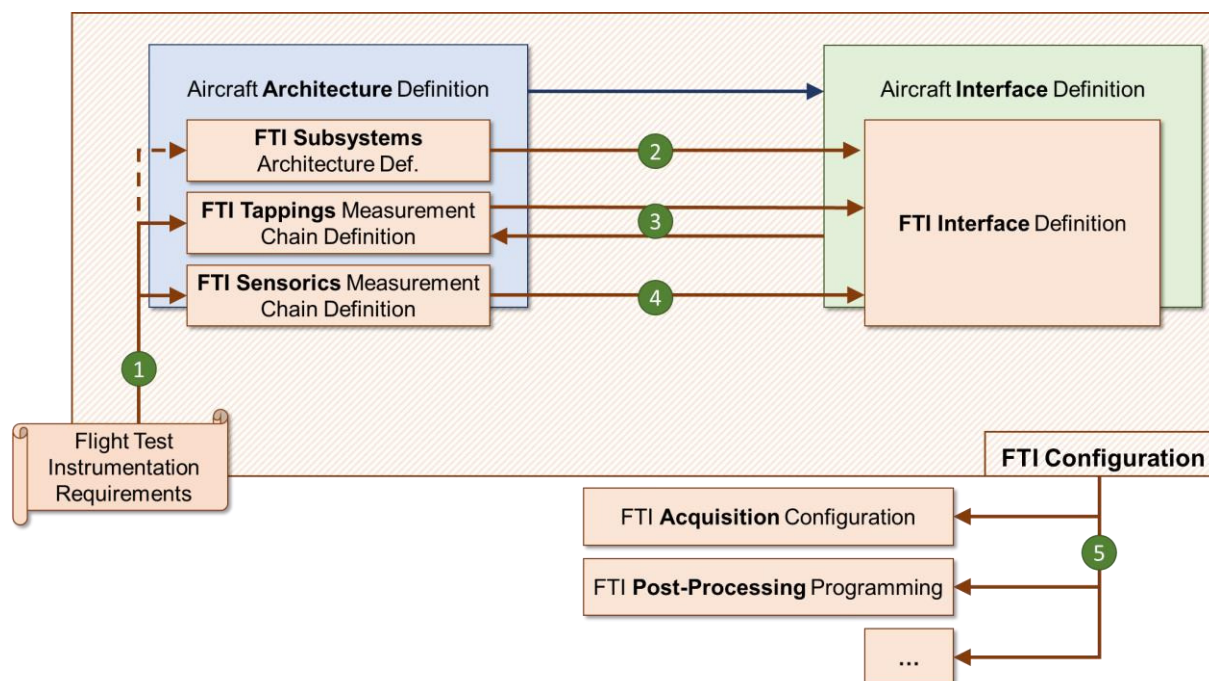


Fig. 10: FTI landscape integrated in a model-based framework

FTI Tappings Measurement Chain Definition (3):

Based on the tappings required by the different systems and disciplines, these are implemented on aircraft and routed up to FTI system for the acquisition – sometimes through conditioning equipment, when required. The acquired data is then routed towards recorders and/or telemetry or on-board FTI computers for its real time monitoring.

The definition of tappings within the architecture model can follow any of the approaches described in Section 2.2. The bidirectional relationship between the architecture and the interface models (see Fig. 10) represents a significant advantage of integrating the FTI into the MBSE model: on one hand, the architecture model is detailed at the electrical and functional levels within the interface model; on the other hand, this detailed information feeds back into the architecture, providing data regarding the parameter to be acquired or the functional ICD of a specific bus. Integrating this information across the model simplifies the configuration of FTI acquisition units and enables a true end-to-end process, bridging the initial architecture model and FTI specific tools.

In the example of Fig. 11 (see 2 in the figure), the left side only shows a FTI tapping connection between the Flight Management Computer and the Engine Control Unit, whereas the right side defines the details of the two ARINC 429 connections corresponding to that tapping, including the label, message or parameter number of those buses.

FTI Sensorics Measurement Chain Definition (4):

In a similar way, dedicated sensor measurement chains are defined based on flight test instrumentation requirements. Sensors are connected to FTI acquisition and it must be ensured that the sampling frequency, synchronization and acquisition integrity

meets the requirements. In this case, as illustrated in Fig. 11 (see 3 in the figure), the connection from the architecture model is detailed down to the specific definition of the analog output, including the pinout, sampling rate, or the associated parameter, among others.

FTI Configuration (5):

The information aggregated within the architecture and interface models is essential for the primary objectives of FTI: enabling data acquisition and analysis. Consequently, FTI equipment must be configured by leveraging data from both models to populate and drive FTI-specific tools. Key applications include:

- **Data Acquisition Units Configuration:** Defines specific flight parameters to capture, including data types, sampling rates, and message structures.
- **Post-Analysis Tools:** Programs post-processing software automatically using acquisition parameters, combining them with time-synchronization data and raw recordings for deep analysis.
- **Live Telemetry Monitoring:** Translates raw data into readable formats using the detailed functional interface documents, enabling flight test engineers to monitor aircraft parameters in real time.
- **On-Board Data Processing:** Converts raw parameters in real time during flights making use of specific embedded FTI software, providing the crew and specialists with critical data and situational awareness.

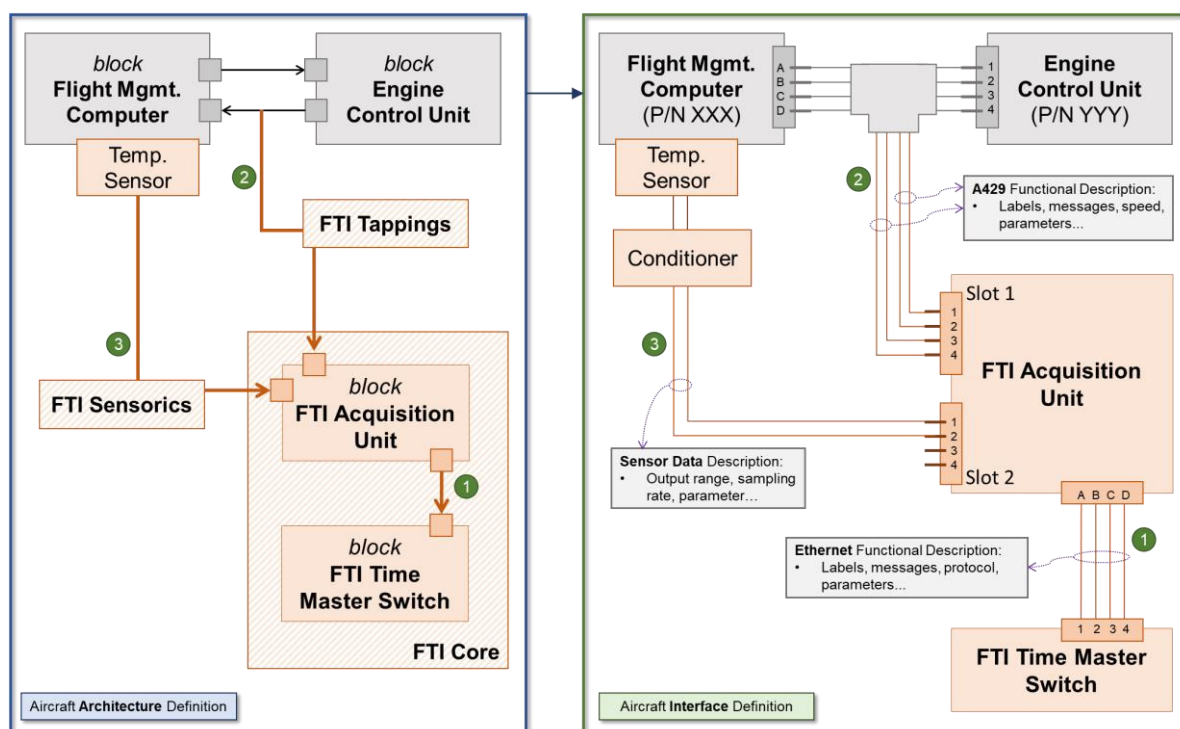


Fig. 11: FTI architecture definition refinement into FTI interface definition

Closing the loop, FTI design, its electrical and functional implementation and its configuration remain fully traceable towards the flight test instrumentation requirements, supporting FTI design verification.

7. Conclusions and Future Lines of Study

This paper has explored the application of MBSE methodologies beyond high-level FTI architecture modelling towards detailed definition of electrical and functional interfaces. It has been shown howappings, sensors and other specific FTI elements are traced in a model-based environment.

FTI systems have a temporary nature, a strong dependency on aircraft interfaces and evolve continuously with prototype configurations. In this context, FTI systems can be seen as a demanding application domain for MBSE methodologies.

It is highly valuable to have a consistent and digital traceability between FTI architecture, aircraft systems architecture, FTI interfaces, and aircraft interfaces. However, the application of MBSE to FTI requires important adaptation to keep flexibility, rapid iteration, and enable the definition of specific FTI artifacts. MBSE modeling methodologies are captured in manuals to ensure shared standards and languages between all the model's stakeholders. These must include specific adaptations required for modeling FTI system that have been described in this article.

There are future lines of research that are worth to investigate further:

A possible line of study could be the integration of safety and security analysis within FTI model-based environments. Incorporating safety and security viewpoints into the same traceable digital environment could further strengthen FTI development processes.

In addition, having FTI system interfaces modelled – as the rest of aircraft systems – may permit to anticipate FTI software development and FTI verification activities, taking advantage of virtual engineering solutions and avionics benches at early stage of the project.

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