

Mini-Multi Interface Box Simulator (MMIBS)

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Abstract. Today's military and commercial aircraft avionics and general systems are built around complex networks of intelligent devices. Maintenance and troubleshooting of these systems often require access to the data bus or networks connecting the system components. Whether it is on the integration test bench, Final Assembly Line (FAL) or at the Maintenance and Repair Organization (MRO), these tasks are usually performed by means of many, expensive, heavy and intrusive equipment. The MMIBS (Mini-Multi Interface Box Simulator) is a very compact, portable, multipurpose, lightweight, low-power, and easy-of-use electronics test means intended to improve digital aircraft ground testing and maintenance troubleshooting. It is capable of perform functional testing and simulating aeronautical equipment through most common aeronautical communication interfaces, such as AFDX, CAN BUS, ARINC 429, MIL-STD-1553, RS-422, RS-232, RS-485, Discrete and Analog I/O and RVDT (Rotary Variable Differential Transformer) reading capabilities. Besides, the system is highly configurable and reprogrammable by means of intuitive Python-based scripting. System is also able to be controlled with an intuitive, user-friendly and dedicated HMI (Human Machine Interface). In this mode, the user can conform a MMIBS WIFI network, allowing multiple MMIBS operating in parallel to cover complex testing scenarios. The MMIBS device integrates all the aeronautical communication and signaling in a volume of 12x12x12cm and weight of 1200g and provides an autonomy of 5 hours. In this way, our solution combines performance, reliability, low maintenance costs, and ease-of-use to support efficient ground maintenance operations.

1. Introduction

The new aircraft systems design trend to be more electrical and digital in order to reduce space and weight but also increase the testing and maintenance capabilities with significant cost reduction [1]. This allows providing digital solutions with highly integrated software functions dedicated to increase the auto-testing capabilities of the aircraft, allowing reducing the intrusiveness since the number of ground test means decreases for production and maintenance operations. These kind of auto-testing functions are very interesting for the new civilian type aircrafts which have large demands and where systems and optionals are usually the same from one customer airliner to the other. However, for military aircraft type applications, it is very difficult to standardize common solutions as normally the countries requests on-demand customized products. For the production of such aircrafts and for



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maintenance of those legacy civilian types already in operation, which does not have such auto testing capabilities, the need of Ground Support Equipments (GSE) to simulate flying conditions is very important when conducting ground test operations.

There are commercial and portable GSEs which usually are specifically dedicated for each system, to simulate its flying conditions, like GSEs for Air Data System, Radio Altimeter and TCAS (Traffic Collision Avoidance System) and other examples like those found in [2]. These GSEs are normally dedicated to maintenance and support troubleshooting of those particular systems. However there are many cases where to test other systems in simulated flying conditions, like for instance the Autopilot (AP) or the Ground Proximity Warning System (GPWS), there must be the need to simulate complex and coordinated scenarios including, usually, systems like Air Data, Radio Altimeter, or Reference and Attitude. To achieve this, several GSEs must be deployed, to stimulate such systems, and strongly synchronize the data they are managing so their outputs are used to inject the required signals to the systems under tests (AP, GPWS). These data normally are of the type of aeronautical digital buses like the ARINC 429. The deployment of such GSEs for those complex scenarios needs to invest lot of time and human effort and in some cases, due to its complexity, the scenario is not well reproduced. There are other alternatives to the use of commercial GSEs, as self-dedicated simulators/test means for each type of aircraft, but normally with the impact of low flexibility and portability as well as high impact in cost.

Therefore, in order to provide an easy-of-use, portable, rapid deployment and non-intrusive test support to any aircraft ground operation scenario, Airbus in conjunction with SkyLife engineering have developed a very compact, multipurpose, lightweight, low-power electronics ground support test mean, so called MMIBS, Mini-Multi Interface Box Simulator, intended to improve aircraft ground testing and maintenance troubleshooting. It is capable of performing functional testing and simulating aeronautical equipment through most common aeronautical communication interfaces for legacy and newcomer aircrafts.

2. Methodology

The development of the product was performed according Systems Engineering V-model methodology [3], from Concept – Stakeholder analysis to verification phases of the prototype, through the SRR, PDR, CDR and verification reviews. The concept definition, specification and verification were responsibilities for Airbus while the product development and manufacturing was conducted by SkyLife. There were two major iterations. A rapid prototyping to confirm that concept size requirements were feasible and then a longer and dedicated iteration to establish the final hardware and software design.

2.1. Concept and Development Phases

As a first step Airbus Defence and Space Manufacturing Engineering Transversal Systems department, prepared a CONOPS (Concept of Operation) for the MMIBS, identifying the most common use-cases and interfaces needed for ground test in Airbus Defence and Space production FALs for C-295, A400M and A330-MRTT mainly. Following use cases were identified as more relevant:

- Be able to read data from almost any aircraft interface under a single, integrated and compact solution.
- Be able to ensure correctness of aircraft harnesses when no real equipment is installed, for “plug and play” optional deliveries.
- Be able to simulate almost any aircraft equipment (Hardware in the loop) to:
 - ensure that systems receiving inputs from others can be tested (eg. AP, GPWS, TCAS, etc.) under flying conditions;
 - ensure that production and maintenance operations are not stopped when no spare aircraft equipment is available.

- Be able to ensure data security, mainly for military applications.
- Be able to be fully programmed and configured by means of an user-friendly python language API (Application Program Interface).
- Be able to provide the following modes of operation and any combinations between them to:
 - interface with the Ground Test Systems of FALs, like the Airbus CATS (Computed Aid Test System), which is used to centralize, manage, simulate and record production ground test operations and data;
 - provide network operation of MMIBS units under a centralized Human interface;
 - allow MMIBS to work in autonomous mode, reading and simulating data depending on the script instructions loaded into it.

A trade-off between potential solutions and architectures was conducted to be compliant with the related use cases, allowing making the definition of the following high level requirements for the MMIBS:

- Hardware capabilities needed:
 - Size and Weight: 120 x 120 x 120 mm, 1200 g (see Figure 1);
 - 1 x MIL-STD-1553 dual redundant bus;
 - 8 x ARINC429 Tx/Rx;
 - 2 x CAN Bus;
 - 1 x Redundant AFDX / ARINC 664;
 - 1 x Serial RS-422 / 485;
 - 1 x Serial RS-232;
 - 1 x Optional ARINC 717 (expansion);
 - Continuity/Isolation cabling tester capabilities (expansion);
 - 8x Analog Inputs / 4x Differential;
 - 4x Analog Outputs;
 - 8x Discrete Fully configurable;
 - USB scripting loading / downloading;
 - Optional USB data saving;
 - Battery for 5 hours operation as minimum;
 - MMIBS display mainly for autonomous mode;
 - Electrical supply of standard 230 VAC;
 - Provide at least 20% expansion capabilities;
 - A set of control buttons to allow setting the different MMIBS modes;
 - Support to hang up/install MMIBS in any aircraft zone.



Figure 1. MMIBS prototype. Size compared to a smart phone.

- Provide user-friendly Human Interface to read data with the following features:
 - read in binary, Hexadecimal or engineering;
 - be able to select and display the bits of interest;
 - provide dedicated screens for each type of interface and common ones for inter-interface scenarios;
 - provide dynamic and static screens;
 - provide on-line simple scripting to allow on demand engineering readings;
 - export the readings to .CSV or similar format;
 - allow introduce simple messages transaction tables for simulation;
 - prepare a dedicated Display for RVDT readings.
- Provide a dedicated Python API (Application Programming Interface) to allow rapid scripting and testing.
- Be able to rapidly reconfigure any MMIBS through copy/pasting scripts from one unit to the other.
- Be able to interconnect different MMIBS units, which are allocated at different aircraft area, without the need of deploying long harnesses (Wi-Fi).
- Introduce also LAN connectivity between MMIBS and Anti-Malware means to allow data security.
- Ensure a cost effective solution, competitive against the most similar commercial solutions.

The first and crucial development step was the achievement and demonstration of a miniaturized and portable basic functional solution concept. For that, following steps were done:

- Skylife identified the commercial miniaturized available hardware.
- All hardware was integrated in laboratory conditions demonstrating the feasibility of achieving space requirements.
- All interfaces were tested through single message transfer under a low level and simple SW code.

After first development step was successfully achieved, a longer development cycle was followed to implement the rest of the SW and HW features: the system firmware written in C running in a Linux OS, the API and HMI defined in Python language with multi-OS support and the final envelop

and hardware design to incorporate all the interfaces. Different designs reviews were conducted as agreed in the project plan. Finally, two identical prototypes were produced.

2.2. Verification phase and results

During the design reviews, the space allocation and expansion provision requirements were satisfactory proven, checking that, for instance, ARINC 717 also could be implemented in future if requested.

A HW Verification Acceptance Test was the first to be performed, ensuring that all interfaces and pin connectors were correctly working and not delivering undesired electrical current which could damage the aircraft equipment HW. In particular the discrete line tests were satisfactory tested. Also the implementation of the buttons, display, Wi-Fi and Land communications were tested, as well as the Anti-Malware SW incorporated.

Laboratory tests were performed to ensure that all the electronic interfaces modes, connectivity to HMI, multi-connection between MMIBS and connection to CATS had been correctly implemented. Finally, the following tests were done using Aircraft Systems Integration test benches or real aircraft:

- Reading and simulation scripting tests were performed for systems like Attitude Reference System, Air Data Systems and Radio altimeters which allowed confirming A429 capabilities.
- Airbus engineers were able to simulate a complete Principal Flight Display (PFD) for the C-295, based on the simulated outputs from MMIBS A429 for those systems, so demonstrating that just one MMIBS could substitute three systems at once.
- Through other Military Systems installed in one Airbus aircraft, the Mil-STD-1553B performance was checked. The readings were in accordance to the Military Design documentation.
- An AFDX troubleshooting case was prepared and it was confirmed that MMIBS capabilities allowed discovering the failure in A400M.
- The analog and RVDT readings was tested with a real RVDT taken from A330-MRTT aircraft, confirming the rotation position marked by the RVDT.

No dedicated tests for the serial buses type and CAN were conducted in real aircraft scenario since the use cases for such type of interfaces are less demanding than those tested for ARINC 429, AFDX or 1553B. However, they were tested between both MMIBS prototypes and also with other laboratory standard receivers for that type of buses, confirming its correctness behaviour.

3. Discussion

Despite there are good HW options and GSEs in the market which support part of the use cases determined by Airbus engineers for MMIBS, there is not integrated solution which covers all of them in such compacted, portable, wireless connectivity configuration, including all requested modes, integrated HMI and rapid scripting. In any case, such commercial products confirms that the number and interface types, requested and implemented in MMIBS are correct and makes it a very capable testing platform for current and future aircraft ground test operations, as identified in [4-5].

Based on the open-source data available, as examples, MMIBS can be compared to Aeroflex DT400H, AIM interface cards, Altadt converters and Astronics Omnibus solution [6-9]. These solutions are very focused on the ARINC429, Mil-STD-1553 and AFDX.

Although one of most common tools for ground test of ARINC 429 is the DT400H, it is limited to just two receiving and one transmitting port, and just able to simulate 16 labels. This is not enough to simulate major part of aircraft equipments. As example, one of the real use cases identified for MMIBS, and tested, is to simulate around 60 labels for a particular ARINC429 output. Also as indicated in the verification chapter, three equipment were simulated at once so it means at least three transmitting ARINC429 interfaces.

On the other side, other companies like AIM provide dedicated solutions based on portable cards for ARINC 429 and 1553, and computer modules for AFDX. To read and simulate data through

portable computer it should incorporate different cards, but not all MMIBS interfaces would be even covered. Also it should be necessary to introduce the PBA.pro SW with different modules. The MMIBS HMI and Python API offers an integrated SW platform covering all MMIBS interfaces at once, which make it very cost effective for the complete set of its interfaces. Altadt offers also dedicated SW and very compact converters between ARINC429-Mil-STD-1553 but it is, again, not covering all interfaces needed as per Airbus use cases identified.

Finally, Omnibus, potentially the closest solution to MMIBS as per the examples proposed, provides a similar solution in terms of interface and modes capabilities. This product supports the idea that MMIBS concept is clearly the future trend for aircraft interface ground test operations as Omnibus is considered by its manufacturer as the next generation appliance for avionics data bus test and simulation.

Comparing both, the size, bigger than MMIBS, and the capabilities proposed for Omnibus shown that it is more adapted to laboratory conditions and uses while MMIBS was conceptually defined for production and maintenance ground operations. Although it provides an autonomous mode, it seem to not have a way to interface with ground operator as cannot provide information of its own process since it does not provides display on it and or controls. It is remarked that has wireless protocols as expansion capability while MMIBS offers that by default. Also Omnibus offers AFDX (ARINC664) as expansion only. Omnibus obviously is not supporting CATS as it is an Airbus Defence and Space ground test system, but it is an important key factor for MMIBS since to adapt Omnibus to make it CATS compatible potentially could demand an important cost already saved in MMIBS.

Otherwise, MMIBS expansion is thought for ARINC 717, and others, while it is basic option for Omnibus. Since ARINC717 is based on the ARINC429, Airbus and Skylife engineers concluded that there is no high risk on integrating in future the ARINC 717 in the MMIBS when really needed. The reason to discard ARINC 717 as part of basic features is that it is only used for the Flight Data Recorder (FDRs), the so called “black boxes”, needed to investigate aircraft incident/accident. Usually dedicated HW and SW are used for downloading and analysis of FDRs data. Since FDR is normally connected with just one pair of cables (the ARINC 717 line) from the aircraft data concentrator to the FDR, when there is a FDR fault, it is easily found, making less interesting to have extra capabilities of those dedicated HW/SW for checking the FDR during production and maintenance operations. However for customers not having such tools, then the ARINC 717 option can be good in a GSE like MMIBS.

Another difference with MMIBS is that the API proposal by Omnibus is under C/C+ languages. The Python API from MMIBS allows creating fast test scripts, without the need of compiling, allowing testing them easily making the MMIBS more prepared to be quickly adapted to any new scenario, which is well common on the military aircraft programs. Although, for real time applications C/C+ could be an advantage, the current results obtained with the simulations and records through the MMIBS API does not show any drawback with regards to timing simulation. Also, it must said that MMIBS concept was to support production and maintenance operations, less demanding than certification ones which could request highly precise real time simulations.

To close, none of the commercial solutions discussed provides functions to check continuity and isolation of the harnesses. It is well relevant during production to test them, moreover when there is no aircraft equipment to support the test, since they will be delivered as “plug and play”. There are plenty of GSE to do so. However combining the MMIBS with an extra switching box controlled by MMIBS, would allow automatizing these tests without practical workforce load reducing costs and even increasing quality avoiding human errors. This provides a good expansion optional for MMIBS to support production ground test operations.

4. Conclusions

The MMIBS product has demonstrated to be a very good candidate to support most of the ground test operations, in any environment like FALs, MRO or in service, where complex scenarios are set, and where there is a big contribution of aeronautical interfaces. MMIBS HW is very compacted and

portable and provides good connectivity and operation modes solutions, including a very easy-to use HMI and API.

MMIBS is demonstrated to be the state-of-art solution for current and future aircraft platforms. The most relevant data buses have been proven in real aircraft scenarios, like C-295, A330-MRTT and A400M.

Currently the prototypes have acquired a big maturity level and the industrial plan is being defined in Airbus Defence and Space to allow launching the serial production phase and provide plans to develop the optional functions identified.

Acronyms

AFDX	Avionics Full-Duplex Switched Ethernet
AP	Autopilot
API	Application Programming Interface.
ARINC	Aeronautical Radio, Incorporated
CATS	Computer Aided Test System
CDR	Critical Design Review
CONOPS	Concept of Operations
FAL	Final Assembly Line
FDR	Flight Data Recorder
GPWS	Ground Proximity Warning System
GSE	Ground Support Equipment
HMI	Human Machine Interface
I/O	Input / Output
LAN	Local Area Network
MMIBS	Mini-Multi Interface Box Simulator
MRO	Maintenance and Repair Organization
MRTT	Multi Role Tanker Transport
PDR	Preliminary Design Review
PFD	Primary Flight Display
RVDT	Rotary Variable Differential Transformer
SRR	System Requirements Review
TCAS	Traffic Collision Avoidance System

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