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Real Time Data Validation Embedded System for Flight Test Using Common Portable Devices

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Abstract:

The flight test data acquisition and data storage process require the integration of a dedicated Flight Test Instrumentation (FTI) for gathering accurate measurement. In a given test flight are performed several test points, which validation requires strict compliance with various predetermined conditions (e.g. 10s speed stabilization at 230kts ± 2kts @1σ). Furthermore, for several test flights the validation of a given test point carried out at the Fixed Telemetry Ground Station (FTGS) doesn't solve entirely the problem, because in some cases, the pilot needs additional information (e.g. Command forces), which are not displayed in the aircraft cockpit instruments, to control the execution of a given test point. For small aircraft (e.g. AT-29) there is no available space for FTI and data processing system installation and this precludes the integration of advanced crew information systems. However, the computing power grows of new mobile systems (e.g. Tablets) opens new horizons for the development of such advanced information systems. Therefore, the Instituto de Pesquisas e Ensaios em Voo (IPEV) developed and integrated an airborne ultra-compact information system to be used for real-time test flight managment and decision-making or test data processing, validation, displaying and data reduction analysis. Flight tests conducted by EFEV (i.e. Brazilian Flight Test School) 2017 class students were used to evaluate the software and the results were considered satisfactory.

Key words: flight test, real time, data acquisition, data validation, mobile devices.

Introduction

Nowadays, mobile devices usage in flight tests campaigns has increased due to the availability of Flight Test Instrumentation (FTI) wireless components (e.g. IEEE 802.11 - Wireless LAN).

Wireless sensors and Wireless Data Acquisition System (DAS) are offered by companies as a solution for acquisition and validation of flight tests data [1].

In a fighter aircraft where its inherent limited space is a major constraint for installing FTI components, the conventional wired network can be exchanged for wireless network.

Beside the WLAN, there is several other wireless network technologies such as Bluetooth (i.e. IEEE 802.15), but in all cases, the challenges to be surpassed are latency, synchronization and package delivery reliability.

As a general trend, the wireless environment seems to be a reality for the Flight Test community. However, flight safety and data accuracy issues must always be considered for the solution development.

Mobile devices can be used for image acquisition and flight test data processing (e.g. ground weather reference system for Air Data Computer - ADC calibration Flight Tests Campaign) [2].

Another possible solution is the development of a real-time airborne test data visualization application for test point validation.

The implemented solution should consider the current availability of Consumer Off-the-Shelf (COTS) devices. However, the agility in implementing solutions (e.g. apps - application development) and its mobility are attributes that help its integration with legacy DAS.

The availability of real-time data through applications developed under Android environment to be installed in mobile devices for visualization by the Test Pilot is very relevant, because in some cases the Test Crew needs additional information (e.g. command forces), which are not displayed on the aircraft dials, to control the execution of a given test point.

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Such feature improves flight test efficiency because it guarantees a successful execution of all test point, mostly when such trials should be performed within a predetermined range of several control parameters (e.g. Stick displacement).

On large aircraft (e.g. KC 390) a complete flight test data acquisition, processing and validation system can be installed within the aircraft. In this case, the necessary information for the correct execution and/or validation of the test point could be easily presented for the Test Pilot and Engineer. On the other hand, on a small aircraft (e.g. A-29 Super Tucano) the space constraints avoids the installation of FTI along with the data processing system.

So in this case, there is no possibility to integrate advanced information systems into the Test Bed. However, the computational capacity evolution of advanced processing devices opens new horizons for the development of such ultra-compact airborne information systems.

The objective of this paper is to discuss the development of a compact airborne system for FTI data processing to aid the Test Pilot in flight trials for the determination of aircraft static and dynamic stability parameters. To do that, FTI data was sent via UDP (User Datagram Protocol) to an airborne computer installed into the A-29B aircraft.

Such system has the function of processing the income data stream using a customized application program. After processing, the data is sent over the wireless network to be accessed by mobile devices installed in the front and rear seats of the test bed.

Specific applications were developed on mobile devices to receive and display data to the test crew. The data presentation software was designed to display numerical values and specific graphic elements, to allow real-time analysis of the test results, for test point validation, and continuous verification of limits, to avoid the occurrence of risk condition, for enhancing flight safety levels.

The application was validated by the 2017 class students of the Brazilian Flight Test Course carried out by EFEV (i.e. Brazilian Flight Test School) and the results were considered satisfactory.

System Architecture

The goal of this project is to provide a way to allow the Test Pilots and Engineers to visualize real-time data inside the aircraft cockpit. In order to accomplish this purpose, it's needed to:

1. Acquire raw data from the FTI;
2. Convert raw data to Engineering Units (EU) data; and
3. Send data for the users.

To accomplish that an airborne Single-Board Computer (SBC) equipped with two Ethernet Interfaces is used to acquire, process and distribute live FTI data. In this application the first LAN port is used for acquiring FTI data over UDP protocol. The second port should send EU data for the users. The selected SBC should comply with MIL-STD-810 standards for shock and vibration [3].

For Test Pilot data visualization, it is used a mobile device with maximum 5 inches screen due to space constraints inside the cockpit.

At the rear seat, to display test data for the engineers, a device with 8 inches screen attached to his leg was considered the best choice. In both cases, crew jettison possibility avoid the usage of any wired solution.

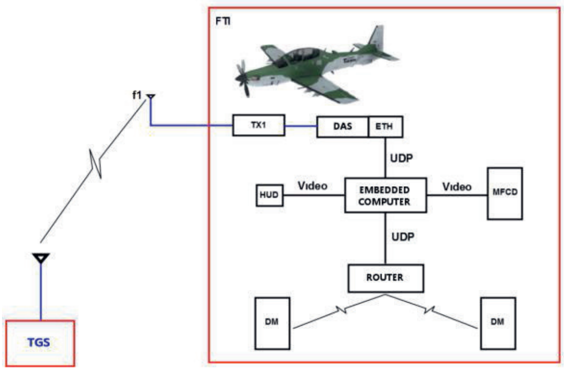

Figure 1. System Architecture

As presented, system architecture was proposed considering its usage for Flight Tests Campaigns and its integration into the A-29B aircraft (Figure 1).

All flight data are provided by the FTI to the airborne SBC thought an UDP connection. The computer acquires, translate, pack and send all data to mobile devices via an WIFI router to make any selected data set available over the WIFI network inside the cockpit.

Two applications were developed in this project as follows:

1. The first one is an embedded program who acquires data from FTI, convert to engineering units and send the results to mobile devices. This application is composed by 3 modules (Figure 2) as follows:

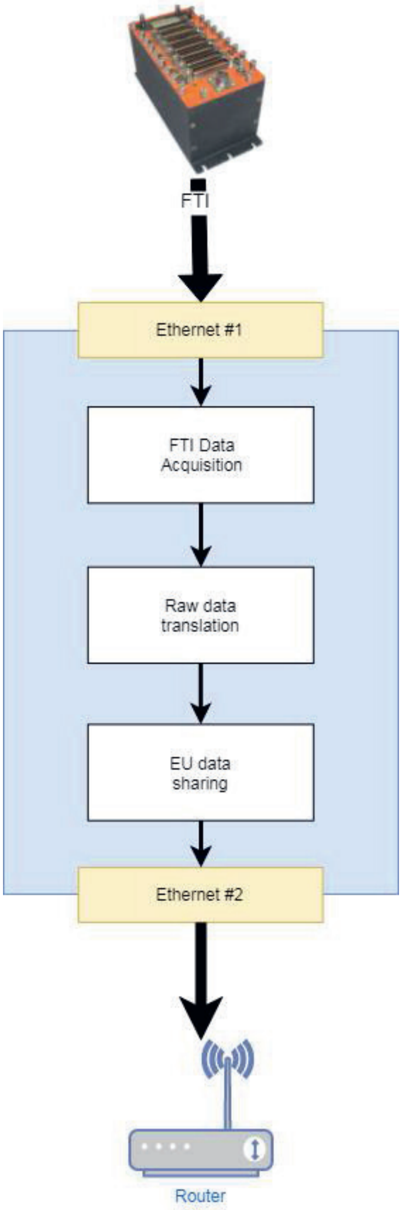

Figure 2. Component Diagram of embedded processing application

a. Data acquisition module who gets all data from FTI through an UDP connection using embedded computer Ethernet interface #1. The module read a XML (Extensible Markup Language) file that contains all FTI configuration, such as IP address, port and UDP packets structure.

b. The processing module that converts raw data to EU. Such software It is a compiled Matlab® function and it provides controlled and updated calibration information that assures an exact data conversion.

c. The distribution module, thought an UDP connection using Ethernet interface #2, shares all EU converted data to the WIFI network.

2. A second application was developed to get all data provided by the embedded application thought the WIFI network and display them to the Test Crew. This application is required to display data in numeric and graphic formats (i.e. gauges and strip-charts), change gauges and strip-charts configuration and group data by maneuvers.

System Integration

The A-29B aircraft FTI was changed to comply with specific needs to this project for the inclusion of UDP connection and additional hardware installation. The SBC and router installation is depicted in Figure 3.

Figure 3. Embedded computer and router installation

As presented, the SBC was installed in the aircraft trunk and the router in the cockpit.

The Mobile Device used by the pilot was installed next to aircraft front panel, on the Head-Up Display (HUD) left side.

The engineer tablet was installed in a specific base over his leg using a COTS flying clipboard (Figure 4).

Figure 4. Pilot and engineer mobile device installed

The pilot device was kept in pilot's field of view to allow external and HUD visual references visualization information during flight the execution of test point and data reading. This setup provides feedback information to help the pilot to correctly apply the flight techniques and to properly control and maintain the Test Bed within the required flying conditions providing a

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concise situational awareness to assure a safe flight. Furthermore, the device position allows ease and user-friendly access so the Test Crew could also change displays pages and device configuration during the flight.

Ground and Flight Tests Execution

For flying a modified aircraft due to the FTI and the proposed system installation into the test bed, it is required the issuing of a Special Flying Permit by Instituto de Fomento e Coordenação Industrial (Industrial Fostering and Coordination Institute - IFI) who is the Brazilian Military Certification Authority. So for the verification of the modified aircraft compliance it was performed several ground tests that includes electromagnetic compatibility and interference, physical and critical cabin compliance.

All results were considered satisfactory and there was no significant WIFI network interference on the aircraft systems.

The equipment installation ergo metrics was considered satisfactory by test crew and the inspectors of certification authority.

At the end the Special Flaying Permit was issued, and the system evaluation Flight Test Campaign was executed for system final validation.

For system verification, it was selected the A-29 static and dynamic flight qualities syllabus of the 2018 class, of the Brazilian Flight Test Course, carried out by EFEV. Such evaluation was composed by several Test Points as depicted in Table 1.

Table 1. Selected System Validation Tests Points

Point	Zp Ref (ft)	Vc Ref (kt)	Configuration
Flight controls check (PAL check)	-	-	-
Take off	-	-	TB/FDN
Stabilization	10.000 12.000	130 160	TR/FR
Mechanical characteristics of the Flight Command System (MCFCS)			
Longitudinal static stability and acceleration & deceleration			
Short-period			
Dutch roll			
Phogoid			
Steady sideslip aproach			
Maneuverability			

In addition to the listed Test Points (Table 1), crew staff performed cabin critique to evaluate the tool operation during the execution of the flight tests. It was also verified the tool suitability for test data presentation, its update rates, scales and graphic elements to follow and control the execution of test points.

Finally, system operation evaluation was performed based on implemented functionalities and configurations.

Results

While on the ground, for the execution of the flight controls checkpoint procedures (i.e. PAL check), the application was considered very useful for adjusting and validating the pilot command inputs.

During the tests it was also possible to display the evolution of command position values, as the pilot advanced with command inputs.

While in operation, it was also possible to perform a FTI parameter check before the aircraft take off. Such procedure improves FTI data reliability and reduces the occurrence of refly because this tool easily indicates the occurrence of any parameter degradation to allow an early FTI data non-compliance detection.

Several evaluation reports indicates that this system improves Test Crew situational awareness because it enables the continuous monitoring if the actual aircraft flight condition is within its cleared flying envelope, to avoid unnecessary violations. Moreover, it also helps the crew to properly execute the test points as required by the test order.

Another relevant point to be reported is the fact that test points are often performed outside ideal conditions or even in non-valid conditions because in the aircraft cabin the pilot and test engineer do not have access to all control parameters involved in the test.

This fact implies the undesired repetition of test flights and it causes direct impacts to the execution of the flight test program increasing its execution time and associated costs.

However, with the use of this application, it was possible to verify in real-time the actual flying conditions from the beginning to the end of all executed test points.

Such feature allows a careful evaluation of the test results by the Test Crew and therefore the validation of test points while the aircraft is still flying. This enhancement improves flight test campaign efficiency.

As an example, for the execution of the Dutch Roll and Short-Period test points, the Test Pilot needs to excite, the dynamic modes of the aircraft over its longitudinal and directional axes.

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The recommended flight technique for evaluating such flight qualities is dependent of the pilot amplitude and frequency inputs on flight controls.

As reported the developed application played a key role thought the validation of the curves plotted at the mobile device of the command and surface positioning parameters.

Such validation process allow the Test Engineer to warn the test pilot when he needs to adjust the maneuver.

Moreover, after the excitation, it is also possible to verify if the aircraft responded accordingly and to view the test results on the mobile device screen.

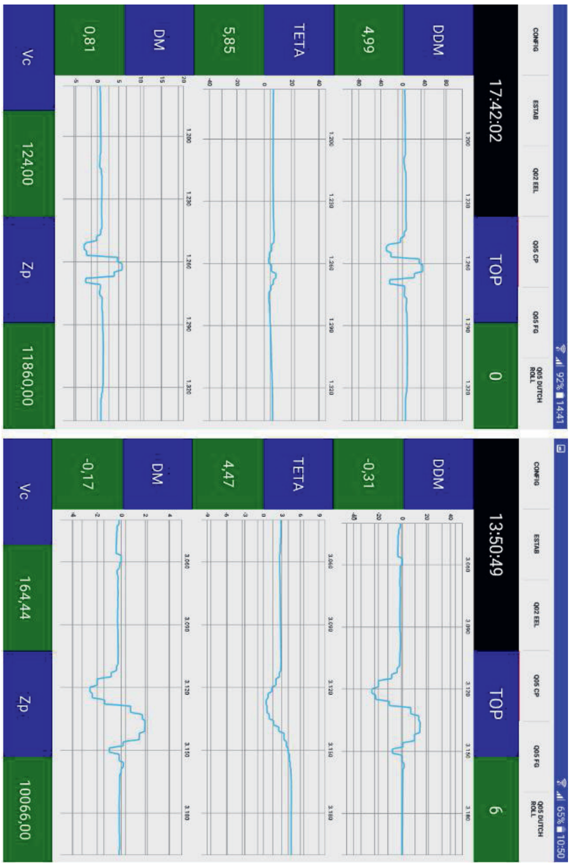

Figure 5. Doublet inputs: (a) not valid; (b) valid

Figure 5 shows an example of a Short Period with Doublet input for longitudinal axis excitation as follows.

1. The first chart (i.e. Figure 5a) depicts an asymmetric and short duration input therefore the dynamic modes were not properly excited. Such conclusion could be verified by the TETA (i.e. Angle of Attack) parameter trace.
2. The second chart (i.e. Figure 5b) depicts a valid input where the modes are properly excited resulting in a greater amplitude response of the TETA parameter.

As presented with the introduction of this new tool, it was possible for the test crew to analyze and evaluate the validation condition of the test point and to eliminate false perceptions. It should be noticed that such conclusion would not be possible using only data presented in the original cockpit displays and dials of the aircraft.

The test crew also reported that the devices did not interfere with the regular aircraft piloting so the flight was still safe with such equipment installed into the cockpit.

Finally, the observed results were considered satisfactory by the 2018 class Flight Test Course pilots, engineers and instructors for the execution of instruction Test Flights and real Flight Test Campaigns. In addition, the use of the tool was very well accepted by IPEV's testing community that foreseen the possibility of using it in several other flight tests applications.

Conclusion

Mobile devices can be very useful in the development of airborne applications, because they are built with well integrated resources such as cameras and accelerometers. In addition, its easiness for development, validation and integration of new software on the Android environment speedup the process of implementing innovative and/or customized solutions.

In this development it was demonstrated the safe and reliable use of these types of devices for flight test applications.

In addition, the presented results were validated during the instructions flights of the 2018 class of the Brazilian Flight Test Course.

Future developments should encompass, the integration of the tool with the aircraft Multi-Function Color Display (MFCD) and HUD.

Such development may also approach the development of new facilities for test data presentation and insertion of graphical aids for the Test Crew (e.g. flight director, specific excess power) aiming the correct execution of the testing techniques, improving Flight Test efficiency and safety.

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