RESEARCH ARTICLE OPEN ACCESS

Integration of FTI Configuration Management with Flight Test Database for an Enhanced Digital Twin Development

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ABSTRACT
Flight test instrumentation configurations traced on aircrafts are carried out across various projects and multiple experimental platforms in each. Up to now, managed our configurations in Excel spreadsheets, ERP systems, Jira, Teamcenter, Doors, in-house tools etc... Apart of these multiple complex systems, flight test data management part requires additional systems such as Optimus (in-house), IADS, etc.., much more complex. Managing all these independent media, causes the work effort to divide between time management optimization and FTI configuration management.
Consolidated FTI Configuration management systems with flight test data management system in one FTI medium will ensure data integrity, accuracy and reliability. This more accessible and unified system will also be the foundation for us to develop a digital twin to presents the unpredictable correlation between flight test data and FTI architecture in the future so that condition monitoring based on Deep Learning and ML algorithms, and configuration management operations can be used in our pre-flight and post-flight activities.
***Keywords* –** Big Data, Configuration Management, Digital Twin, FTI, ML/DL

Date of Submission: 01-06-2025 Date of acceptance: 11-06-2025

I. INTRODUCTION

Efficient Flight Test Instrumentation configuration management is a must in a multi-project environment. Current methods involve disparate systems, causing division in effort and accessibility. This paper advocates for integrating FTI configuration management and flight test data management systems into a unified medium to enhance efficiency and traceability. With this unified system, the main goal is to create an FTI digital twin.

FTI MANAGEMENT HISTORY

Having a dynamic FTI network that can and will change in almost every flight test also means monitoring and managing multiple media to monitor the sub-parts of the system. Although the management of these media is essential to trace the system, it also brings the following difficulties.

Each media is in a different medium. Followed system and their sub-medias can be categorized as follows according to FTI management purposes.

II. FTI OPERATIONS

Teamcenter by Siemens [1] is the media used for management of flight test instrumentation product tree.

A sheet-based list where we track the instrumentations on the aircraft based on their naming format and the data acquisition unit they are installed in.

Jira by Atlassian [2], where the health status and anomalies of instrumentations in flight tests are monitored & reported to FTI engineers and malfunction activities are initiated based on the findings.

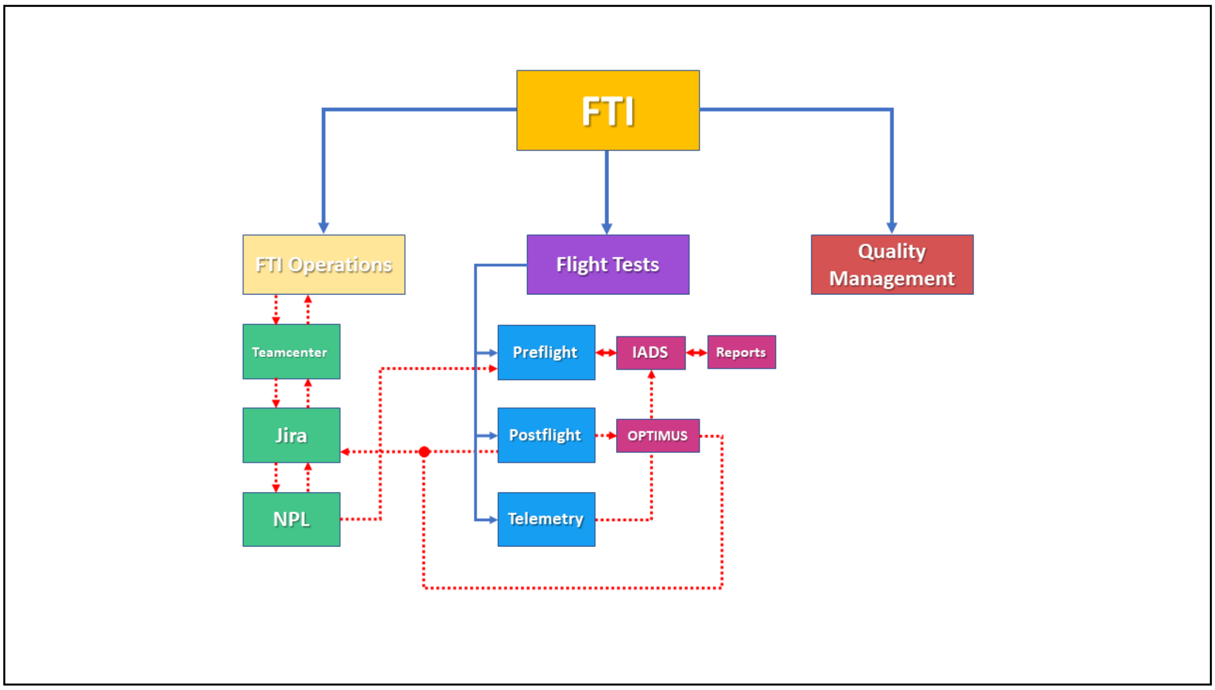

Fig 1 – FTI Management Flowchart

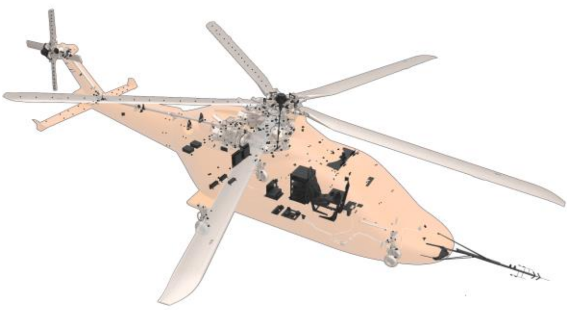

Fig 2 - Figure of FTI System in 3D, Teamcenter

II.I A/C Configuration

Aircraft configuration management in Teamcenter is not in true focus to picture FTI systems in 3D model based to track. FTI parameters are not just names, they are supposed to carry multiple imprints within them to trace.

Even though the 3D model-based configuration given in Figure 2 provides information about the instrumentation to the user, it is insufficient in parameter tracking because it does not contain information such as sensor serial number, structural part serial number and calibration date. Hence reaching the desired resolution becomes a difficulty.

To manage daily changes made on FTI system in Teamcenter requires transitions between different medias. One of them is Numbered Parameter List.

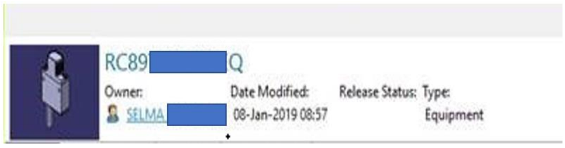

Fig 3 - Teamcenter sensor naming format, RC short for Rotor Craft, 89 as FTI ATA Chapter

Parameter No	Zone	Requester	Measurement Name
TAC701	7	ATA0330	TR Rotation Speed

Fig 4 - Numbered Parameter List sensor naming format, TAC short for Tacometer, 701 as the first tacometer of 7th zone on aircraft

Flight tests campaigns performed on multiple prototypes and the same day changes that may come with it create conflicts between the product and FTI, and the traceability of this kind of dynamic configuration management creates engineering challenges and increased work effort. In addition, Teamcenter does not indicate the correlation between instrumentation and post flight data.

II.II Numbered Parameter List

Numbered Parameter List, aka NPL, is a sheet-based file in which to keep track of parameters in the FTI system on the aircraft and can be called the backbone of FTI configuration management. Through this file, monitoring and managing the sensors and digital lines on the aircraft can be done. Even though it is a file full of tables, NPL actually makes a sheet meaningful thanks to its set of rules. Parameter naming rules is determined at the beginning of a project, can only give a first impression of both the type of a sensor and its location on the aircraft. If a parameter is named POT805, one understands that this is the 5th potentiometer located in the 8th zone through the imaginary divided zones of the helicopter. By checking the potentiometer sheet in NPL, one can access the identity of this sensor and how the data it depicts is interpreted.

Of course, the only purpose of this 6-digit name format is not to represent the type of sensor and the region where it is located. Parameter number represents a region, mechanism, the parameter itself, where data will be collected on the rotary wing. In every prototype of the project, on board or not, the name of that parameter where data is collected by FTI, is always the same.

Although this situation ensures traceability and sustainability in a way, it also becomes possible to form conflictions between FTI configuration of the aircrafts. NPL files are updated with a new version name with each change, to reflect the dynamic FTI system. The user records the changes in a history log file. Since it is a human-based system, there is room for greater errors on working for multi-projects and platforms.

Each experimental platform of a project has its own NPL file. To manage the parameter history and match them with the aircraft's own configuration and flight tests, the NPL version is updated with every minor change. This method was applied so that the monitoring of a parameter is more accessible. Although this situation also ensures traceability and sustainability in a way as well, it also becomes possible to form conflictions between FTI configuration of the aircrafts since it is still a human-based system on a multi-project and platforms environment. Which shows that the parameter name may be insufficient for the NPL entries in the FTI configuration management in the Teamcenter product tree.

II.III Jira by Atlassian

Flight Test Instrumentation deficiencies can be detected during flight tests and these deficiencies can be flight abort or can be solved as soon as condition permit. FTI Jira system deficiencies can be defined by flight test engineer, system designers, flight test instrumentation engineer. The system log status presents not only the instrumentation improvement history also keeping the knowledge about the problems.

Having Jira to track and record these problems or improvements is not completely sufficient for FTI management. In order to understand the problems and interpret what kind of action should be taken, it is essential to first make sense of the post flight data and view it from the FTI perspective. To achieve this, data has to be plotted and examined over time intervals. For this case, OPTIMUS, the in-house flight test database, is used and the connection between the FTI configuration of the flight test and the Jira findings gets to be accessible.

III. FLIGHT TEST MANAGEMENTS

There are formalized processes to control and maintain the FTI system before, during and after each flight tests or campaigns. In this process, the FTI engineer has to access different media in various locations, without a network between them. These can be summarized as follows.

- IADS, to monitor parameters before and during flight tests in telemetry rooms
- Numbered Parameter List, to obtain the FTI configuration
- Preflight reports, to access previous activities performed on the aircraft
- OPTIMUS, the in-house flight test database developed to share flight tests' post data with design teams

III.I Pre-Flight Tests Activities

Preflight test activities performed before the flight test, to see that the FTI system is ready for this operation and to prove that the flight test critical parameters are healthy and consistent. To document and prepare the report of this, an FTI engineer should first obtain the real-time data gathering from the analog and digital parameters on the aircraft to the data acquisition system with IADS, match it with a numbered parameter list, to see that the configurations match. Anomalies should be recorded and indicate the activities that have occurred on the aircraft since the previous preflight, if any, such as a sensor to be removed from the network.

Although this activity is only valid for 24 hours, dedicating the work effort spent to perform it to more than one project and the multiple platforms requires serious planning ahead of time. Documents reflecting these activities are recorded in FTI database and informed via e-mail and shared with the relevant teams, and knowing that these works have been completed remains specific to the person performing the activity.

Reviewing the parameters in preflight with the human eye inspection increases work effort, especially on a platform with different types of sensors & data protocols. It requires experienced personnel to carry out these actions and to interpret them well when necessary. Which, may not, fully provide traceability and reliability.

III.II Post Flight Tests

After a flight test, an FTI engineer must obtain the data collected by the data acquisition unit on the aircraft and share it through the internal network so that it can be examined in detail by the analysis/design teams. For this, the raw data needs to be matched and interpreted with our configuration files created via NPL. In the past, FTI engineer would share this after matching the data with configuration files through IADS. This process would take a long time and effort, sometimes more than half a day. Nowadays, thanks to OPTIMUS, the flight test database developed by TUSAS Helicopter FTI & AI Teams, engineer responsible for the platform only needs to use a single system to share flight test post data and it takes a few minutes to perform the necessary set-ups.

III.III OPTIMUS

After approximately 1 hour of flight test, the data collected from the FTI system on the T625 platform can consist of 100GB even in compressed UDP packets. In the past, in order to make sense of such large and raw data, IADS data manager was used and hours were waited for the data to be interpreted and exported corresponding to the desired test points.

OPTIMUS is a flight test database and framework developed by TUSAŞ. Created to manage such a large data, even in its compressed form, and to make it more accessible and faster for export.

IV. QUALITY MANAGEMENT PROCESS

FTI engineer makes a statement on behalf of the truth of the collected data. Evidence must be provided to document that the data collected during flight tests reflects the conditions during flight as it is and the calibrations of the sensors are valid. A calibration laboratory system is used to keep the calibration details of the sensors and process them into NPL. This system keeps calibration reports of sensors based on their serial numbers. Values such as the expiration date of the calibration and the sensitivity factor used during the interpretation of the data collected from the sensor are obtained by these reports. Keeping track of sensors that have a short time until their calibration date expires only through reports requires extra workload and continuous monitoring, as there is no countdown-based system that will warn the user in time.

Just accessing these reports requires a separate work effort. Similar types of sensors are used in multiple projects and platforms. Therefore, it must first be known whether the serial number on the sensor in the aircraft matches the serial number value in the NPL of the aircraft with respect to parameter name. Since there are situations where the sensors on the aircraft cannot be physically accessed, this process cannot always be accurate. All these processes are personnel-based and may cause serial number/sensor conflicts due to the human factor. This not only reduces traceability but also increases peer effort.

V. FTI DIGITAL TRANSFORMATION

Almost each of the systems used to manage the FTI configuration is on a separate media. This increased the work effort and limited the accessibility. Based on this, a project has been initiated on a system that is traceable and accessible, aims to collect media in a single environment, reduce work effort and the need for experienced personnel.

As a first step, NPL files were included in the environment of OPTIMUS, the flight database. Along with the flight data of each project and platform in OPTIMUS, the NPL reflecting the FTI configuration of the prototypes is now accessible here and sheet-based tracing is left behind.

By combining these two systems in the beginning, matters below is aimed.

- To follow aircraft data and parameters from the same system.
- Developing a system that will send timely e-mails to FTI staff for parameters that require date-based tracking (Re-Calibration dates, KAD Module Acceptance Tests [3]), while taking advantage of OPTIMUS's user-friendly web interface.
- Accessing reports and documents that track the history and identity of parameters or sensors, based on serial number, from a single place.
- Keeping a log of every change made to the NPL based on versions.

With these changes, all reports regarding the sensor can be accessed via OPTIMUS NPL instead of the distributed systems. Instead of going through the calibration reports for each sensor one by one and checking the re-calibration dates, 3 months before the re-calibration date, warning e-mails are being sent to the user automatically at regular intervals. Only with these changes, work effort has decreased significantly and NPL has become more trackable and accessible.

VI. FUTURE WORK AND DIGITAL TWIN

Main purpose of moving NPL and OPTIMUS to the same environment is just a preliminary preparation for the FTI Digital Twin [4]. Divided into three phases, FTI Digital Twin will display the FTI configuration on a 3D model in a game engine, perform FTI data management & condition monitoring and initiate predictive maintenance activities by making an estimation of sensor health before test campaigns is carried through imitating the environmental conditions beforehand.

The aim of the first phase is to reflect the FTI configuration, sensors and parameters on the helicopter shell within a 3D framework. With this application, which will eliminate the inadequacy of the information provided by parameter names about sensors and reduce multi-media transitions in product tree management, traceability will increase and by communicating with the OPTIMUS NPL system, the imprint information entered into NPL about the sensors will be accessible from a single media.

Phase 2 will combine real-time data with the FTI parameters collected on the 3D framework in Phase 1, and perform health monitoring by passing it through machine learning models that will establish data characteristics on the sensor data in static or dynamic conditions. This system is going to quickly depict the anomaly in the acquired sensor data in preflight activities, as a result, there will be a reduction in work effort. Necessity on the experienced FTI engineer will lessen. Through the data characteristics that cannot be established by the human eye, performed preflight activities will be less prone to deficiencies.

In order to adapt the machine learning models in this process to a dynamic FTI system, the models will be re-trained with offline data, constantly. Therefore, bringing OPTIMUS and NPL together is essential to communicate them with the FTI digital twin system.

In the 3rd Phase, these models where trained with data collected in different environmental conditions, already in the FTI database; and the data characteristic established between the data, it will be able to predict the situations that the sensors will exhibit during flight test campaigns and warn FTI before anomalies occur by simulating flight tests on the game engine. The system will initiate malfunction activities on the sensor before the flight tests, making work effort more efficient.

VII. CONCLUSION

To sum up, efficiency has been increased even by combining the 2 systems included in the FTI configuration, which is managed within multi-media systems that limit work effort and accessibility, the

Digital twin will further optimize this management. It will gather the systems in a single framework and make the activities performed on the aircraft more controlled and accessible by combining Machine learning algorithms within FTI data management.

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