DATA CONSISTENCY CHECKS ON FLIGHT TEST DATA

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ABSTRACT

This paper reflects the principal results of a study performed internally by Airbus's flight test centers. The purpose of this study was to share the body of knowledge concerning data consistency checks between all Airbus business units. An analysis of the test process is followed by the identification of the process stakeholders involved in ensuring data consistency. In the main part of the paper several different possibilities for improving data consistency are listed; it is left to the discretion of the reader to determine the appropriateness these methods.

KEYWORDS

Test Data, Data Management, Data Quality, Data Consistency

INTRODUCTION

Obtaining a clearance for a new aircraft requires a perfectly performed and documented test process. The tests are finalized in reports demonstrating that the aircraft's requirements, as specified by design and authorities, have been fulfilled. To establish a solid baseline for these reports, data must be gathered in numerous tests, to compare the performance of the "Object under Test" with respect to the requirements. If problems occur during the test process which lead to incorrect or unexpected data, it is normally expected that these will be detected during the analysis phase at the end of each test step. This can result in confusion, as the analyst must decide if the anomalous data is caused by the "System under Test" or is a result of a problem in the data gathering process itself.

The amount of data gathered during flight test has grown dramatically over the last 30 years. In the early years of flight test data recording, only a few physical actuators were measured, and the quality of the recording was checked by the system engineers immediately after the test by visual inspection of the data. Later, as aircraft started incorporating bus systems into their architecture, the bus messages were recorded as well. Over the years aircraft systems became more and more complex, introducing the requirement for more and faster busses. Currently, up to a half a million different parameters may be recorded during a flight test. Additional to the number of parameters, the software configuration of the aircraft may be changed much more rapidly than as in the past, due to the use of modern development tools and methods. These methods allow for shorter software cycles and faster data delivery; consequently for the analysis engineer who has been tasked to integrate these parameters into the test environment, it means the available time for testing between the different software stages has been shorted, too.

In the past, the aircraft configuration, as specified in the Interface Control Document (ICD) was very stable, and the analysis engineers were very experienced with this data and the underlying data description. They could easily decide if problems encountered during a test had to be forwarded to the design department (in case of a system problem) or back to the test department (in case of a data gathering/data processing problem). Unfortunately today no one system engineer is able to have in mind all thousands of parameters of the "System under Test"; fortunately this is not necessary in the most cases, as only a small subset of data is required routinely to complete an extensive analysis of the test points performed during a test. Only when a problem is detected is a more detailed view of the data required, and at that point, it is expected that the recorded data be of good quality.

This expectation of good quality data requires that all organizational units supporting flight test must avoid errors in data gather and processing, as far as this is possible. This imposes the requirement to perform as many data validation checks as possible, to identify errors and potential problems, before the data is released to the analysis department; at the very least users must be a warned if the data has been identified to be spurious. Naturally, it must be acknowledged that the data validation and verification process entails costs in terms of time and money, but proper data verification in an early stage of data generation and data processing will produces savings in the long run.

DEFINITIONS

To avoid any misunderstanding, the test object will be referenced as **"System under Test"**, when discussing the different steps in testing and data validation and verification.

Data validation means the process of gathering data is correct and the accuracy of the data has been checked. Dedicated validation tests against known values in laboratory have been performed.

Data verification means that the data, gathered during a test has been checked on plausibility and reliability before and after data processing.

DATA VALIDATION PREPARATION: PROCESS ANALYSIS

To understand the criticality of this problem, we have to consider the stages of test execution which influence data gathering and data processing:

- During the project planning phase a test program, which defines the test objectives and the test tasks, must be created.

- During test preparation (for the whole test program) the test environment must be designed, installed and documented. The Interface Control Document (ICD) must be transferred to the test department, must be analyzed and understood and must be made available on the test equipment, for the setup of data recording. Single test points are derived from the test program, and written into the test plan. Then the planning of the individual tests can start. Every test point must be transferred to the test plan and must be documented.

- After the completion of planning the test can be performed; the test data is acquired, transmitted and recorded.

- After test execution the recorded data is submitted to the organizational unit responsible for the processing of the test data. Certain preliminary data quality checks are performed.

- Lastly the organizational unit responsible for test data analysis must analyze (and check) the test data.

From the list shows that many different organizational units are involved in the process, all which support our effort in the validation of the data.

IDENTIFYING STAKEHOLDERS

The next step is to identify the stakeholders of the particular process step or steps to define responsibilities and clear channels of communication. The actual organization identities of stakeholders may vary from organization to organization; the list below is provided only as an example:

- Stakeholder one: The Design Department (hereafter: Design) which must provide Test- and Analysis department with the description of the internal digital and analog interfaces of the system under test.

- Stakeholder two: The Flight Test Instrumentation Department (FTI) which is responsible for collecting measurement requirements of the object under test from the analysis department. The FTI also is responsible for the design of the measuring system and for the installation and maintenance of the sensors, the data acquisition system, the telemetry system and the recording system.

- Stakeholder three (remote testing only): The Telemetry Ground Station (FTGS) which is responsible for the reception of the telemetry data stream and the further processing of the telemetered data. FTGS is also responsible for the distribution of the processed data to the monitoring stations and strip chart writers of the analysis engineers. FTGS also provides the monitoring SW in the monitoring rooms.

- Stakeholder four: The Data Processing Department (DP) which is responsible for post flight processing of the “raw” recorded test data into various formats suitable for further analysis. The DP also may provide simple tools for data visualization and investigation.

- Stakeholder five: The Analysis Department (hereafter: Analysis), which checks the processed data with respect to the system requirements. Analysis also may also provide (or to request) special analysis SW for higher level data analysis.

Once it is defined which stakeholders are involved in the process, it must be analyzed which checks should be performed in each phase of the test.

DATA CHECKS FOR DIFFERENT PHASES OF DATA

Different data validation and verification methods may be used during the phases of the test program's life cycle; the methods presented in the following sections are listed with respect to their relevance to the particular test phase. If automatic data validation/verification is to be performed during any test phase, the overall requirements of the test department must always be considered. Some of these checks are trivial, but are included here for completeness. Many of these suggested "best practices" recommend what is to be done, but not how; whether they are to be employed in whole or in part must be decided on a project basis. The methods listed are structured according to stakeholder and test phase.

Checks during Project/Test Program Planning

The "Design" stakeholder should:

- Define the ICD format; taking care to ensure that the data formats for every source, for the data itself and for data from an external supplier is uniquely defined.

- Define Data busses and messages. Bus specifications should not be violated, existing bus designed should be used and complex data structures should be avoided.

- Prepare the Interface Control Documents. These documents should be made available in an electronically readable format to all stakeholders, to reduce effort and eliminate typographic errors. Every parameter of the system under test must be explicitly specified by the ICD. This specification must explicitly define a message or system position, as from the viewpoint of the "FTI" stakeholder, a parameter is a measurand which is measured from a certain place in the system. A formal ICD change process must be established, in order to ensure that changes to the ICD content due to the correction of errors or other issues are uniquely identifiable and well documented.

The "FTI" stakeholder should:

- Define all sensors, checking measurement range and hysteresis against the requirement.

- Prepare a sensor database, in which all necessary sensor information should be stored. The physical minimum and maximum values of the sensors should be defined in this database for later reference.

- Prepare a database of test parameters, composed from the different ICDs; the plausibility of the data descriptions must be ensured. New ICD data must be compared with previous versions of the ICD data and any differences must be made public to the analysis department.

- Define the Airborne Data Acquisition System (ADAS) layout. The capacity of the system must be checked against the requirements; as much system information as possible (even ADAS system information) must be collected. The compatibility of ADAS modules with system interfaces must be analyzed. For further processing the ADAS configuration metadata shall be made available as digital data for automatic reuse. All decisions of FTI regarding the onboard data acquisition must be done in accordance with the DP department, to avoid later problems or misunderstandings with the DP.

- Define the recorder layout. The criteria are quite similar as for the ADAS. It is important that for the layout of ADAS and recorder the interface modules are operated in accordance to their design. Recording discrete signals via RS244 interfaces is a possibility, but not recommended.

Test Preparation and Test Setup

The best practices for test preparation (for the overall test program) and test setup (for a particular test) are presented in this section. Many of the steps described here as occurring at the beginning of a test program, will reoccur in later stages as well; for this reason I have presented both stages of the test process in a common section. In order to ensure the consistency and integrity of the data, all organizational units involved should hold regular meetings. It is a must that all configuration changes be communicated to all stakeholders involved.

For the preparation of the **Data Acquisition System** the stakeholder FTI should:

- Check the requirements against the capacities of the system.

- Check the calibration of sensors, for sensors, where coefficients are provided by the supplier. The calibration data should be available in digital format and this data should be compared with other calibrations of the same sensor.

- Check the calibration for self-maintained sensors. For this purpose a calibration and documentation process be defined, which includes a periodically recalibration plan. It is good practice to define reference maneuvers and repeat these maneuvers during the test periodically; statistics obtained from flight test data can and should be used to compare results from calibration to calibration. Very important parameters can be externally stimulated to check their functionality (temperature sensor by a heating device, accelerometers by knocking or jarring it). Parameters which have a known value at the begin of the test are very easy to check by standard procedures.

- Compare similar parameters from Test-Rig recordings with Flight Test Recordings for discrepancies and anomalies.

For the preparation of the **Recording System** the stakeholder FTI should:

- Inform the data processing department of any recorder configuration changes, with electronic data exchange being preferred.

- Record test data with new recorders.

For the preparation of the **Data Processing System** the stakeholder DP should:

- Provide a single database for all data.
- Provide an interface for data access for all data sources.
- Provide test data to analysis department.

For the preparation of the **Data Analysis** the stakeholder Analysis should:

- Validate parameter database content by analyzing data as gathered from a qualified and documented ground test and processed by the DP department.
- Organize quality gates to ensure coherence of parameter descriptions between different organizational units.
- Verify the online monitoring displays with data from a qualified ground test.
- Check input parameters of analysis software after ICD change with respect to data format (i.e., int, float) and engineering units.
- Ensure version control of different analysis software stages, corresponding to different software stages of the system under test.
- Perform data validation reviews to ensure that all parameters essential for the evaluation of the system are present and verified.

Test Execution (single test)

After all preparations have been accomplished the test will be executed. Before online monitoring can start, the FTGS must perform a checkout of the setup of the telemetry system. It is recommended that unique configuration information should be sent via the programmed data stream of the system under test. This information is used to compare the incoming datastream with the setup of the online monitoring system.

Once the data transmission has started, it is good practice:

- To predefine certain displays, which display either fixed or know data to verify the correctness of the complete data chain.
- To execute a defined set of maneuvers at the beginning of every test to have comparable data of dynamic sensors.
- To record telemetry dropouts during test, to identify spurious online data as telemetry faults.

After the test has been performed, the recorded data will be processed by the Data Processing department. DP should:

- Archive the original data in unprocessed (“raw”) form for every test.

- Check, if available, the documented recorder interfaces against recorder internal interface setup description.

- Check, if available, errors reported by the recorder, and check recorder internal stored performance and maintenance values (temperature, interface load, …).

- Document all problems during data processing with timestamp.

- Check again ADAS data stream's unique configuration ID against DP Setup description.

- Check PCM frame counter stability.

- Check recorded bus data messages against bus data message documentation, count messages and analyze message timings.

- Validate recorded test data by doing plausibility checks of selected parameters.

- Validate recorded test data by comparing selected parameters with results from prior tests.

The results of the checks described above shall be made available to the analysis department.

Data Analysis

After all the consistency checks have been executed, the analysis department should have reliable data for further analysis; nevertheless all data must be examined critically. In the case of doubts about the quality of the data, the data in question should be investigated by comparing the questionable data with the same data recorded from different sources.

CONCLUSIONS

Data verification is a must. Automated processes should perform as may plausibility checks as possible; but the design of these checks must be the product of careful consideration. Parameters selected for automatic plausibility checking must be selected individually, depending on the physical behavior of the parameter. For example: For a "heading" an average value makes no sense, but for an AOA or a voltage, statistical values such as upper and lower limits, mean and standard deviations can indicate changes in the behavior of the underlying sensors. From this small example we see that the establishment of automatic data verification will cost much time end effort.

The ICD requires very much attention. It must be ensured that on issuance of ICD data that the originator of this data distributes this data to all stakeholders/departments involved – simulation, ground test, flight test, data processing and analysis – at the same time and with exactly the same content. Currently, the conversion of the ICD data to department specific data formats are performed for the most part by the individual departments, starting with the ICD data as delivered. In the future, it is strongly recommended that a signal organizational unit should provide the ICD information in some final format for all stakeholders. Each test (ground, software, etc.) should contribute to the validation of the dataset, leading to a gradual but continuous increase in the quality of the data for every user.

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