

Original Article

The Role of Flight Test Data Analysis in Development Flight Testing

M Khasyofi¹ *

¹ Flight Center Division, PT Dirgantara Indonesia, Jalan Padjajaran No. 154 Bandung, Indonesia

* Correspondence: mkhasyofi@indonesian-aerospace.com

Received: 10 August 2023; Accepted: 3 November 2023; Published: 1 December 2023

Flight test purposes is to evaluate aircraft design and performance. Nature of flight test are hazardous and expensive so that it have to be planned well to ensure safety and effectiveness of the mission. Any data obtained from flight test must be utilized to get comprehensive evaluation of the aircraft characteristic. Flight test data play central role in aircraft development. As part of flight test team and flight test program, data analysis support aircraft designer to evaluate flight test data, data reduction, and determine the quality of flight test data. This paper described flight test data processing and flight test data analysis role during flight test program from industry perspective. Flight test activity or flight test program start with the purpose whether for experimental, development and certification or production. Flight test program activity can be divided 3 phase: flight planning and preparation, flight test execution and flight test reporting. During flight test execution and flight test reporting, test data have to be process, distribute, and use properly. Data from aircraft and flight instrumentation were process from raw data format to engineering unit. Data noise and error during flight test influenced by atmosphere condition, instrumentation, experience etc. Using several method in data reduction process, this error could be minimized as possible. Technology information make data processing and analysis process faster and more efficient. Some example in this paper came from industrial perspective during development new type design aircraft in Indonesian Aerospace. Case example from this paper based on experiences during development and certification N219. For other aircraft case it may be more complicated or simple. Development of technology such as computation, electronic, and communication bring new method in data analysis. As digital technology increase amount of data and sensor capability to produce high resolution data make big data analytic should be considered as solution to improving data analytic capability in flight testing

Keywords: flight test; flight test plan; data analysis

1. Introduction

1.1. Flight test program

When we start to design flying car, drone, aircraft or any flying object, we have to perform flight test. In order to validate design and simulation model which is developed during design phase, flight test have to be plan well. Unfortunately, flight test result could be different from simulation or laboratory. Engineer or designer used flight test to validate or improved theirs's mathematical model. Even though design technology, computer and electronic technology make it possible to perform flight test in lab or simulation, but there still several condition that have to be performed in real environment. In some situation aircraft behavior is only discover when it is fly, so that flight test is essential in aircraft development.

When flight test has to be performed, safety is the first concern. The other requirement are valid data and the objective of test result. This combination of all requirements should be described in flight test plan. Flight test engineer and test pilot who conduct the flight have to know the objective of the test and systems related. Sometimes it involved a lot of people from different discipline from the person who design the aircraft to program management even stakeholder and contractor. Flight test program activities can be divided 3 phases: flight planning and preparation, flight test execution and flight test reporting. Flight test planning ideally started parallel with design phase or as early as possible. During design phase, test planning prepared based on the design requirement and designer also considered how their's design will be evaluated. The example for test instrumentation installation that should be defined in design phases. Man power who conduct test execution need to be trained properly. The other aspect related management and scheduled such as budget and investment. Flight test is expensive and require extensive resources, qualified personnel and involves many parties. General flight test activist can be seen at figure below,

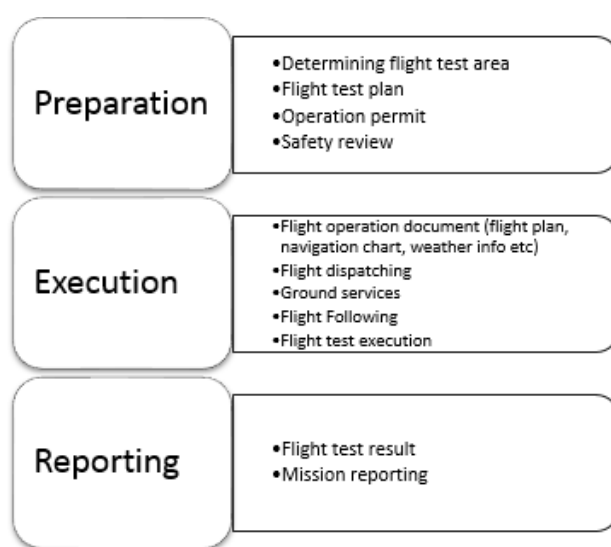


Figure 1. General flight test activities

Flight test activity or flight test program start with the purpose whether for experimental, development and certification or production ref [4]. After the purpose of flight test was defined, the next step is to create flight test planning. Flight test planning defined all aspect during flight test activities form aircraft configuration, flight test subject, location, crew involvement etc. Flight test plan used as guidance during flight execution to make sure flight is conducted safety and efficiently. In parallel preparing flight test plan, flight operation department prepare operation permit such as aircraft insurance, crew authorization, test area etc. if required, survey area are needed to make sure all support test facilities ready to use and to coordinate with local authority. After all preparation is completed, all aspect off safety during test was reviewed by safety review board.

The next phase of test activity was flight test execution, this phase is challenging for flight test team and very dynamic situation. Flight schedule and a lot of task need to be consolidated and coordinated with all interested parties. During flight test execution, engineer, designer, mechanic and other parties involved and determined final configuration for certification. Some troubleshooting, repair, maintenance or design improvement agenda should meet schedule and to minimize delay time or over budget. Good coordination among the participant and good planning is very important for the success of test program.

The final activities is flight reporting. The result of flight execution are reported to the design office for design evaluation. During the development test, flight test could be evaluated in single

flight or several flight. Flight test result from single flight could be reviewed after landing in post flight briefing. in order to decide the next test subject, design engineer will collect data from instrumentation record and flight crew note or mission report to provide flight test result and analysis. The result will submit to related designer for design evaluation or authority for certification. During aircraft development, flight test result sometimes didn't meet expectation. The aircraft needs small and major modification or even design changes to meet design and operation requirement. This process makes aircraft development project schedule delay or behind the schedule. It is required not only technical but also management skill from high level decision maker. Good management systems in design will help engineer to solve problem and take decision.

1.2. Role and responsibility in flight test

Flight Test Data analysis is one of job in flight test engineering who is responsible for quick look analysis, data reduction, and data presentation. During aircraft development, design engineer need data to verify theirs design or to validate mathematic model. Competition among manufacture push design office to reduce design cycle and develop new product faster and efficient. To make design proses faster, data proses capability is one key element to speed up design cycle pace. Flight test data analytic job could be performed by flight test engineer or other engineer who understand basic principle of flight testing. This role and duties were decided based on complexity of the project whether it need dedicated data analysis engineer to support and evaluate flight test data or not. Data analysis role and responsibility may not the similar in some cases. It depend on the complexity of the aircraft and test scope. For more advance flight test program, data should be distributed and evaluated efficiently to all stakeholder in design. It required more procedure to accommodate each design goal and also in order to give feedback to design office effectively. It will reduce and improve design cycle if data and information transferred well. Form this point, data analysis is very important to make sure each flight produce high quality data. Picture below showed the example of data processing during N219 aircraft development project.

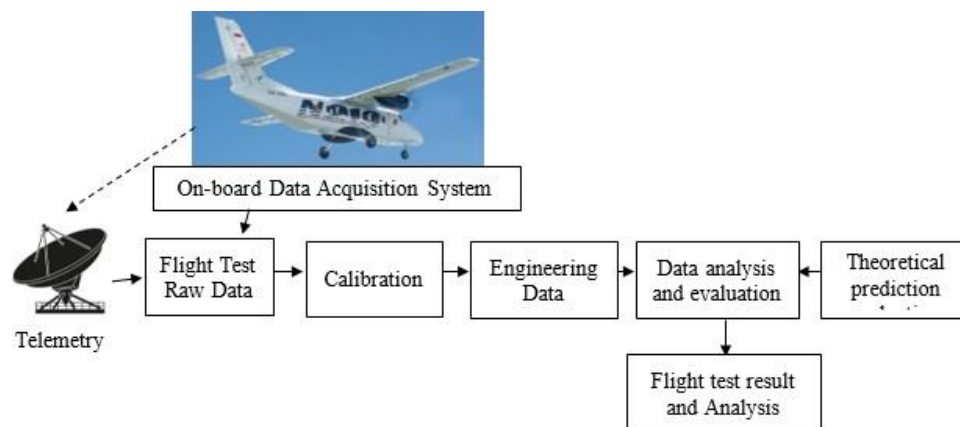


Figure 2. Flight test data process description

Generally, data analysis started from data acquisition proses. Data acquisition from instrumentation such as strain gauge, transducer etc transferred raw data from onboard computer. It involved flight test instrumentation engineer who installed and perform functional check to all installed parameter. The number of parameters, accuracy and resolution was determined based on test requirement. For new aircraft, there was a lot of parameter to monitor all system and airframe. Sometimes it need additional equipment to calibrated basic aircraft instrument and also for backup system. Second process is data selection and pre-processing. This process converted raw data to engineering unit or physical value that was interpreted by engineer. Raw data from data acquisition

system need to be calibrate periodically to produce accurate measurement. Calibration process was performed on the ground and during flight. The next step is data reduction and data analysis. Data reduction is process to extract the most valuable data from specific test. This process sometimes need several algorithm to reduce the amount of data and interpret the result. Data reduction aim was to eliminated noise and bias from various test condition. Data reduction also convert test data to standard condition so that the result form several test could be compared clearly. The end of process was flight test result and analysis. This report is the summary of the all test subject from each department. The result will be reviewed by authority for certification purposes. Ideally flight test result analysis submitted after all test were completed.

2. 2. Data reduction and presentation

2.1. General process

“Data reduction is process of converting, extracting and formatting data such that it can be accepted by data analysis tools” ref [2]. Flight test data from the aircraft process from raw data format to engineering unit. Thanks’ to data processing department who managing this process. Recording data could be analog and digital format or various data format form data acquisition system. It could be from onboard recording system or from ground telemetry recording.

Flight test condition sometimes becoming sources imperfection in data gathering. Data noise and error during flight test influenced by atmosphere condition, instrumentation, experience etc. If we break down more detail, source and magnitudes of error came from instrument, position, reading, atmospheric condition, pilot technique, inaccurate thrust or power determination and error due to control system friction or hysteresis ref [8]. Using several methods in data reduction process, this error could be minimized. Data reduction is process for extracting test data in order to get valuable data with standardization or standard condition. The example during climb performance test, several flight test was conducted to get datasheet for evaluation. Each flight could be performed in different atmospheric condition or different crew. Data reduction could be performed by simple and complex calculation based on type of flight test. Each test subject which is need data reduction method especially for flight physic test evaluation. Sometime data reduction using dedicated software for specific test and data processing. Data reduction software develop inherently with flight instrumentation system and data processing.

2.2. Method and procedure

“Data analysis is the process of scrutinizing the data to ensure its correctness, deriving performance and comparing to the evaluation criteria” ref [4] Several methods was using in data reduction from plotting time histories, cross plot and calculation. Large amount of data and uncertain flight test condition make data reduction is important during flight testing. In the early day of aviation history, some data analytic technique developed using several methods such as approximate equation, time vector method, non- parametric frequency response and analog matching known as classical method [4]. More advanced such as equation error, output error and filter error method found after digital computer introduced. Communication technology allow data analysis was perform using telemetry and online parameter identification.

Time histories plot is represented aircraft behavior parameter in two dimension graph with time domain. This plot intended to record aircraft and crew action during test. For flight test engineer or test pilot, time histories plot could be note and evaluate aircraft behavior as well as evaluate test technique. Cross plot represent relation between two parameters to show effectiveness and consistency.

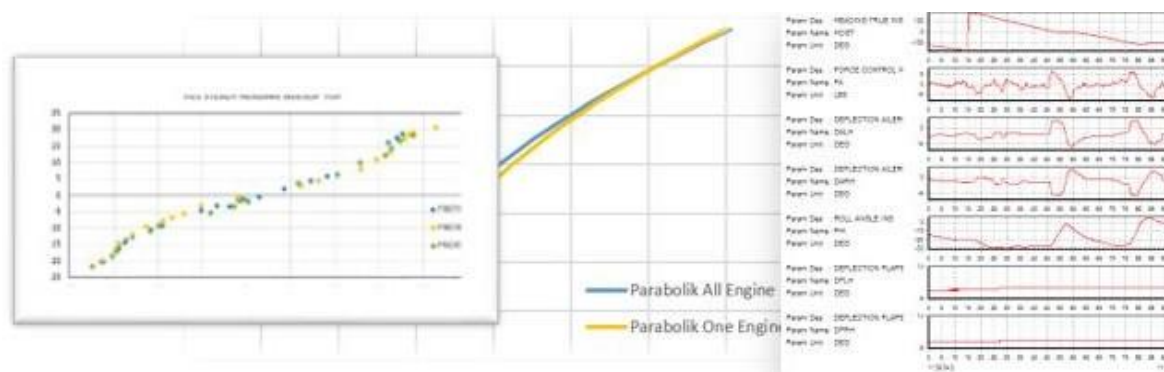


Figure 3. Flight test data result and data analysis example cross plot calculation and time histories

3. Development and future work

3.1. Technology and development

Information Communication Technology (ICT) development makes data become one of commodity and resource for maintain competitiveness. The way we look and process the data become more sophisticated and more challenging. All industry around the world start to adopt digital technology to transform their business. This technology makes process business more efficient and more adaptive in Volatile, Uncertainty, Complexity, Ambiguity (VUCA) era. Big data analytic, cloud computing and artificial intelligent technology were the new of technology and have potential impact in flight test data analysis. If conventional flight test data need computer capability to make data analysis processing faster and more efficient, with internet technology data analytic process will be more advanced and connected. The benefit from computer technology increase capability to gathering, analyzing, processing and storing data real time make positive impact for this process. In the other side, information communication technology will have problem in data security. Without proper data security system, confidential data form flight test face serious threat form hacking and security issues.

3.2. Future Work

Data analysis is topic that often we hear today. in every business sector, several business use data analytic as tool to improve their's performance or to create business opportunity. Digital technology makes data become one of the most valuable assets. In engineering flight testing, data analysis will improve efficiency and effectively in flight test execution. It also will inhance flight safety and increase flight productivity, minimum flight repeat, reducing repeated flight or unnecessary post flight data reduction ref[9]. Digital business transformation in aviation industry create opportunity for development new method in data analysis. As part of puzzle in aircraft design process, flight test data analysis follow development in design technology. Since design process adopted new technology such as computing platform, it should be followed by increasing data analytic capability. One aspect that should be considered is data management. Documentation such as technical report and drawing in digital format could changes in real time have to be informed to all design engineer. Digital platform to connect stakeholder and create right decision during design process is one of challenge. As digital technology increase amount of data and sensor capability to produce high resolution data make big data analytic should be considered as solution to improving data analytic capability in flight testing.

4. Conclusions

The role of data analysis in flight test program is important in order to capture, distribute and process valuable data during flight test execution. The need for data evaluation capability and giving feedback back to design engineer will make design process faster and efficient. In the other hand, flight test activity need to increase flight productivity in the efficient way and reducing repeated flight makes data analysis capability become very important. Technology development in data acquisition, computational and communication open the opportunity to develop new method in data analysis. Some method developed during digital computer replaced previous method influence by technology. Even though new technology to support flight test engineering was introduced, basic principle if flight test engineering is not changes. More complex aircraft system and sophisticated technology makes data analysis become more complex with increasing the amount of parameter to be monitored. Data science and analytic make significant impact flight test data analytic process. If previously we focus in aircraft development and certification phase for data evaluation, it s possible to integrated with operational data. In conclusion flight test data can't be separated in aircraft design cycle and it's role in flight test engineering

References

1. Prihanto A, Kuswardana Y, *Flight Operation Manual*. Flight Test Center PTDI D045-40002 Rev B, January 2014.
2. AFFTC-TIH-93-01, Air Force Flight Test Center Edward Air Force Base, California, Air Force Materiel Command United States Air Force
3. Dominique R and Dirk R, *Flight Test Organization*. European Aviation Safety Agency. 2013
4. Laban M, *On-Line Aircraft Aerodynamic Model Identification*,
5. Hamel P, Aiken William Jr. *Method for Aircraft State and Parameter Identification*. AGARD.1975
6. Stoliker, F.N. *Introduction to Flight Test Engineering*. AGARD.2005
7. Pavlock, Kate M. *Flight Test Engineering Chapter 2 Flight Test Engineering*. Dryden Flight Research Center. Edwards, California
8. Kimberlin, Ralph D. *Flight Testing of Fixed-Wing Aircraft*. AIAA Education Series . Knoxville, Tennessee
9. Wangfeng F. *Flight Test Data Management System Research and Design*. 4th International Conference on Machinery, Materials and Computer (MACMC 2017).
10. Klug C. *Lessons Learned from Applying Data Analytic to Flight Test Data*. ITAE Test Instrumentation Workshop. 2018
11. Webster F and Smith, T.D. *Flying Qualities Flight Testing of Digital Flight Control Systems*. RTO AGARDograph 300 Flight Test Techniques Series – Volume 21. RTONATO.Quebec.2001



This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium provided the original work is properly cited.