FLIGHT TEST DATA MONITORING AND ANALYSIS WITH STK*

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Abstract

A flight monitoring system ohas been developed based on STK and Matlab software. The system is developed to build a system where the real flight test data can be monitored and visualised online, to enable pertinent flight analysis to be performed during flight test onsite, and to enable more detail flight analyis to be processed soon after flight test.The system is mainly consists of four components; the flight data sensor onboard of flying vehicle, the ground receiver, the software MATLAB processing, and the STK flight data visulaisation and processing. On this particular project, only IMU and GPS data are to be measured and visualised. These data is then transmited to the ground using radio modem, and further collected and read by MATLAB from the ground receiver hardware. These collected data is plotted on MATLAB to show the graphical trends, but then tranfered to STK to be visualised in 3D environment and to be analysed further. Several improvent to be added to the system includes adding more plugin and functions to enhance analysis in both Matlab and STK environment, incorporating radar systems to supplement data from the GPS receiver, and performing more advanced post-Flight data analysis.

Key Words: *System Tool Kit (STK), Inetial Measurement Unit, Flight Test, UAV, Rocket*

1. Introduction

Indonesian National Institute of Aeronautics and Space (LAPAN) has been developing technologies for several flying vehicles which includes satellite, rockets and both manned and unmanned flying vehicles. All these developments are under the deputy of aerospace activities which is one out of the three deputy in LAPAN. These activities are mostly conducted in a dedicated research areas located in a 100 hectare land in Serpong, with more than 250 researchers and scientist working on many space development projects. Several other supporting research facilities were also built to support the space development in LAPAN, one of them is the launch site in Pameungpeuk, Garut (Figure 1). Due to its remote location and it close to sea-side areas, this facility is often used for flight testing rockets and unmanned vehicles. This flight test facility, and other related flight test activities are considered to be very important, since it is the end phases of every research and development, to determine the success of the design and development of the whole project.

Apparantly, the cost of flight testing is considered to be very expensive as one of the phases on the development project. For each rocket to be flight tested, for example, the data acquisition and telemetry system has to be installed to get the necessary flight data, and this can be very costly. The success of every flight testing is therefore very important.

Figure1: Flight testing of flying vehicle is an important aspect of development phase

To reduce flight testing costs, an online flight data monitoring using STK is being developed. The system will gather flight data while monitoring the data online while flight testing. The Analytical Graphics Inc's (AGI) STK software will be used to model the flight scenario and the characteristics of the signal path(s) including Path Loss, Doppler, 3D aircraft aspect Radar Cross Section, aircraft dynamics, and the actual terrain of the mission airspace. Agilent's SystemVue will be used to model the Radar System including waveform generation and reception, dynamic range, and radar post-processing, in the RF, Analog and DSP domains simultaneously.

The aims of this project is therefore:
-to build a system where the real flight test data can be monitored and visualised online.
- to enable pertinent flight analysis to be performed during flight test onsite, simultaneously.
- to enable more detail flight analyis to be processed soon after flight test.

2. System Development

The system to be developed is mainly consists of four components as shown in Figure 2. The flight data sensor onboard of flying vehicle, the ground receiver, the software MATLAB processing, and the STK flight data visualisation and processing. The collected flight data from the sensors can be of the form of inertial data (IMU), the trajectory data (GPS or radar), and other health condition and environmental data such as temperature, strain gage, vibration, humidity and others. On this particular project, only IMU and GPS data are to be measured and visualised since these flight data are the most important data to be collected during many flight test in LAPAN. These data is then transmited to the ground using radio modemn, and further collected and read by MATLAB from the ground receiver hardware. These collected data is plotted on MATLAB to show the graphical trends, but then tranfered to STK to be visualised in 3D environment and to be analysed further.

Figure2: Development of flight test data monotiring and analysis

In order to reduce the time and complexity required to develop the online data system here, the use of commercial of the shelf software can have a large impact on the final results. For this project, MATLAB from The MathWorks and Satellite Tool Kit from Analytical Graphics, Inc. are choosen as the cores of the system. In particular, we employed the STK/Integration module to connect MATLAB and STK using STK Connect command, and also to enable STK to interact with other software and hardware. MATLAB is used due to its widespread use in the aerospace communities, as well as the inherent advantages of using MATLAB as a package with a powerful mathematical functions and display characteristics.

Communication between MATLAB and STK is very useful and wotrh to be utilised further. MATLABcan easily automate STK. STK scenario can be created from scratch without having to access STK's GUI. Once a scenario is created, MATLAB can be set up to continually modify a scenario or object parameters for trade study analysis. The results can be re-captured in MATLAB for further analysis.STK can also automate MATLAB. For example, STK can evaluate mission or relative geometric conditions such as range or inter visibility between objects or S/N ratio. When specific figure of mission effectiveness or geometric condition is met, MATLAB can automatically begin additional functions.

Main reasons for connecting MATLAB to STK;

• MATLAB is a graphical programming environment that has very powerful numeric array and string handling capabilities, and easy numeric to string conversion. MAtlab also has Aerospace Toolbox and Blockset which facilitates for advanced analysis for flying vehicles.

• Building user interface in MATLABis relatively simple, which can reduced significantly the development time for the software system.

• MATLAB has basic TCP functions built in Open, Write, Read, Close Connection, which can then be used to facilitate communication with other software and hardwares.

• Additional functions can be easily added to create Connect commands from raw telemetry data to further analyse and visualise the collected information.

Post-Flight Analysis in STK;

• STK can perform attitude analysis form IMU data, which then compares recorded or collected flight test data and onboard video with that simulated using STK.

• STK can perform IMU/Navigation Position Comparison to Radar if available, where STK computes position data between Navigation solution and Radar Data via Access reports.

• STK can perform graphical visualization of position uncertainty at any specified times.

• STK with vector geometry and time tools can enhance the capability of post process telemetry data to analyse any possible scenario or parameter not directly measured during the test, such as relative position to other fying vehicles or expected antenna patterns during flight.

• STK can perform live feed data from other collected sources to be visualised simultaneously.

• STK Advanced Visualization Option provides basicvisual understanding and data check muchfaster than many forms of post-flight analysis

• Capability to define custom angles, times and vectors, via Analysis Tool coupled with Reportcapability in STK greatly simplifies post-flight analysis

3. System Components

3.1. System Tool Kit (STK) version 10.

The Analytical Graphics Inc. (AGI) STK® product is a physics-based software geometry engine that accurately displays and analyzes land, sea, air, and space assets in real or simulated time [1]. STK is used by most Aerospace communities to conduct their system analysis. The core aerospace component of STK includes variousstandard orbit propagators, such as the Runge-Kutta-Fehlberg integrator with eight-order error controlfor advanced orbit analysis (taking into account third-body gravitational effects, drag, solar-radiation pressure etc). The software has evolvedover the years when it was only used by Satellite communities to model and analyse satellites, it has become a great tool for larger aerospace communities. RecentlySTK can also perform modeling and analysisng for aircraft and ground vehicles along with their sensorsand communications. It also models missiles and ships and plansmissions and tests. It models multi-node networks andsensor performance and evaluates the impact of terrain andatmospheric conditions. It predicts mission effectivenessand analyzes mission results.

Here STK is used to:

–model the time-dynamic position and orientation of the flying vehicle during flight test.

–model the characteristics and pointing of sensor, communications, and other sensors aboard the flying vehicles. STK can then determine spatial relationships (e.g. line of sight) between ground station and all of the objects under consideration.

–assess the quality of sensors, computer algorithms etc while also incorporating environmental effects such as terrain, lighting and weather conditions on sensor visibility or communication link quality.

– using communication modul to analyse communication link and antenna analysis during flight test

– using AMM (Aircraft Mission Modelling) to analyse flight performance and design trade of the flying vehicles.

– using Astrogator module to analyse staging and other launch vehicle analysis during flights.

– adding sensor characteristics on the flying vehicles such as antenna, gps, camera, transmitter etc to analyse the sensor performances.

– incorporating MATLAB m functions into STK environment as a plugin to further analyse the system performance of the flying vehicles.

3.2. MATLAB

MATLAB is a high-level language and interactive environment for numerical computation, visualization, and programming. MATLAB can analyze data, develop algorithms, and create models and applications [3 and 4]. The language, tools, and built-in math functions enable you to explore multiple approaches and reach a solution faster than with spreadsheets or traditional programming languages, such as C/C++ or Java™. MATLAB can also be used for other applications, including signal processing and communications, image and video processing, control systems, test and measurement, computational finance, and computational biology.

Here MATLAB is used to:

-read sensor data, in this case attitude sensors (IMU) and position sensor (GPS) and other measured flight characteristics such as strain gages, vibrations, temperatures, humidity.

- Passing the IMU and GPS data into STK to visualise the vehicle attitude and position.

- Plotting the measured data into graphical presentations.

3.3. Software and Integration

The reasons for integrating STK and MATLAB:

•The basic STK process is to define a radar/comm system link scenario with moving TX, RX and interferer objects, analyze the scenario to obtain system metrics as a function of time (such as range, propagation loss, RCS, noise bandwidth, RX signal strength, etc).

•STK can communicate with MATLAB.

•STK does not have any inherent capability for processing any matrix or complex calculations which normally processed by MATLAB.

•MATLAB has many toolboxes for advance algorthms for further signal processing.

•MATLAB users can take advantage of STK's 2D and 3D visualization to viewany geo-referenced or geometric MATLAB data, such as position or attitudeinformation or an antenna gain pattern. Visualizing this data provides an intuitive understanding of it and allows you to view the effects of the datawithin a mission. Large data sets from STK can be loaded into MATLABwhere you can use the native 2D and 3D plotting capabilities to help understand the data and communicate the results.

•By linking STK with MATLAB, an online monitoring from flight test data, until post processing the flight test data can be easily performed on site, soon after the flight test is conducted.

File Inter operability

• Simple process of text file import/export to transfer data between MATLAB and STK.
• MATLAB file import tool can be used to load in STK reports.
• Use STK's external file formats to read matlab data.
• Compatibly independent from operating systemor release versions
• Microsoft COM library open API for programming.
• Object-oriented programming of both softwares.
• Use COM interface to send STK Connect commands.
• Work with events and data providers.
• Windows-machine specific but it removes any compatibility issues between versions and 32 and 64-bit.
• Allows the use of STK plugins.
• Uses TCP/IP socket connection.
• Provides a bridge between STK and MATLAB to use the Connect Command Library.
• Access to MexConnect—MATLAB specific functions designed forusers sharing data between STK and MATLAB.
• Simplifies the setup of the MATLAB Interface by automatically configuring the MATLAB file path for a specific MATLAB version.

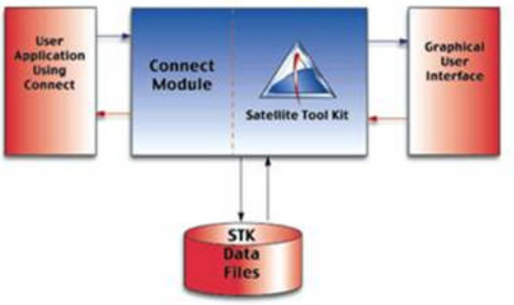

Figure3: STK Connect flow diagram

STK/Connect Commands is used to modify the following data set;

• Scenario configuration:
– SetUnits; SetEpoch; SetTimePeriod
• Animation setup and control
– Animate SetValues;SetTime;Start Forward
• Vehicle attitude initialization example:
– SetAttitude */Missiles/EDF Profile Fixed Euler 10.5
10.9 0.0 23 "Facility/Rumpin Body"
• Flying Vehicle live data:
– SetPosition; Add Attitude (alternating)

3.4. Flight Sensors

The MTi-G INS is a small size and low weight inertial navigation sensor, excellent for control and navigation of (un)manned systems and other objects [5]. The INS is a GPS aided MEMS based Inertial Measurement Unit (IMU) and static pressure sensor. It delivers unprecedented performance for its size, weight, cost and low complexity in use. The unit overcomes typical IMU and AHRS challenges faced in e.g. aerospace and automotive applications.The design of the MTi-G is flexible, providing a wide range of output modes and advanced settings for specific usage scenarios, optimizing the sensor fusion algorithm routine for different applications. It has an onboard Attitude and Heading Reference System (AHRS) and Navigation processor. This low-power Digital Signal Processor runs a real-time Xsens sensor fusion algorithm, providing drift-free, GPS-enhanced, 3D orientation data. Additionally the MTi-G provides inertial and barometric enhanced 3D position and velocity data at a higher update rate than possible with a typical GPS receiver.

Figure4.Theinertial sensor being used to measure attitude of the flying vehicle.

The Development Kit provided allows users to fully explore the possibilities of the MTi-G, and the integration possibilities of the MT with our own system. The system provides 3D Orientation (360°), 3D Position and Velocity (aided and unaided by inertial sensors), and 3D acceleration, 3D rate of turn, 3D magnetic field.

3.5. Experimental Results

Improving and utilizing STK Software were the main activities during this research. STK received attitude data from flight vehicle which will be provided by IMU/AHRS sensor. These angular motions (roll, pitch, and yaw) will then be displayed as vehicle simulation on STK environment. How to connect the streaming data to the STK became the most challenging work on this research. This paper consider Matlab/Simulink programming tools to develop communication between attitude data from flight sensor to the STK simulation software. Figure 5 explains experimental setup of flight data monitoring and analysis using STK used in this research.

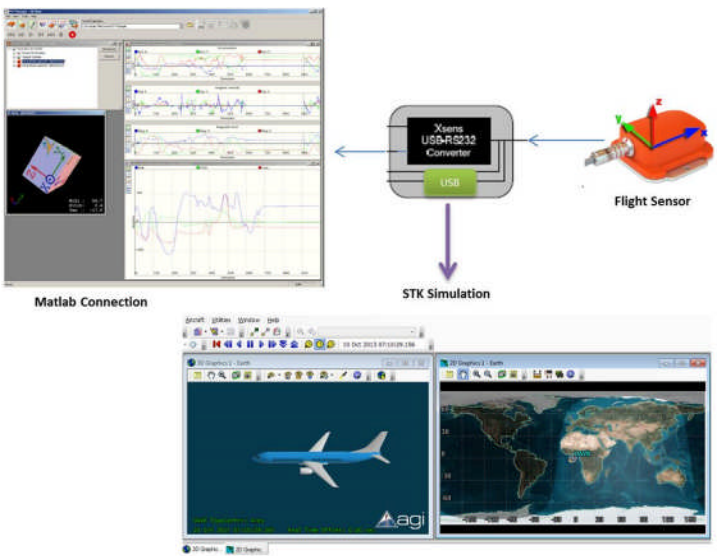

Figure5.Experimental setup

Flight sensor sends attitude data to the STK block under Simulink environment. This STK block is a connecting block developed to run on the same PC. This block will generate command inputs to STK software which will display all attitude data as flight simulation. The simulink block arrangement can be seen on Figure 6 below.

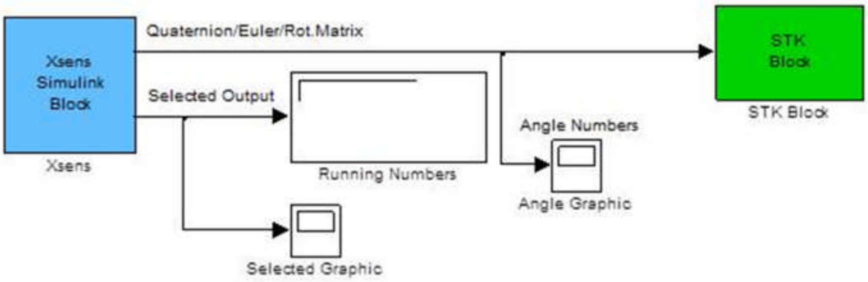

Figure6.STK block under Matlab/Simulink

There are some options that can be selected during flight test to display flight data. These options are selected before vehicle is flown. These data selection can be found by simply double clicking XSens Simulink block, or right click it and then choose mask parameters. Inside this masking block we can choose some of flight parameters that can be used for our flight monitoring and analysis.

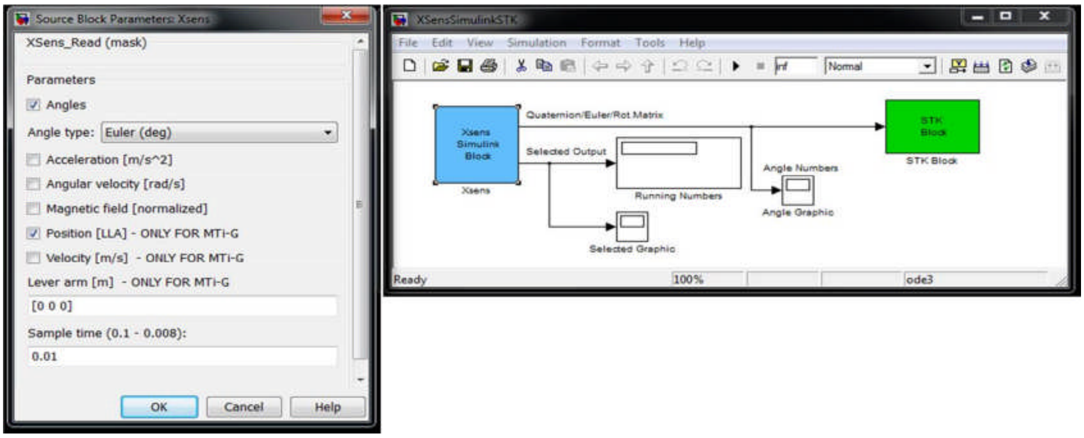

Figure7.Flight parameters on STK block

Experimental on the ground should be done to calibrate this flight monitoring and analysis setup. Sensor simulation of XSens IMU/AHRS is proposed and can be shown as the following figure:

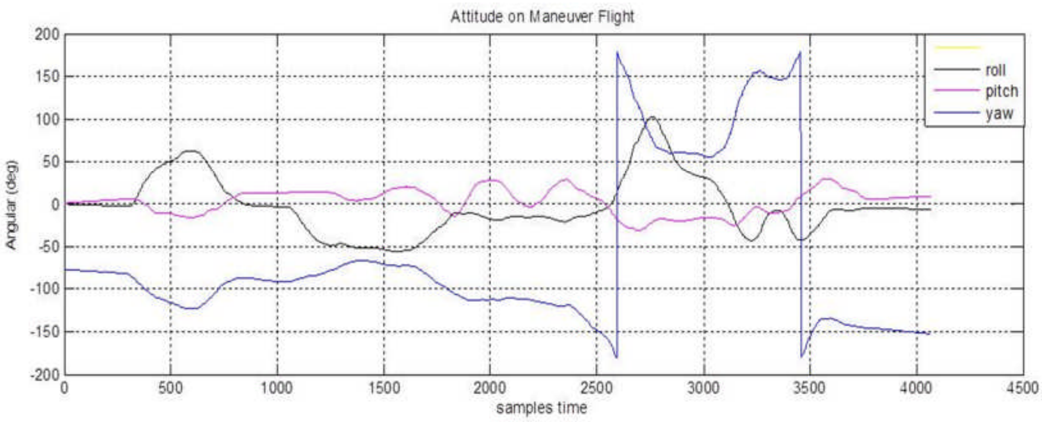

Figure8. Experimental data

Figure 8 above represents flight behavior through IMU/AHRS sensors. It can be seen that the vehicle is doing maneuver to the right side on the lateral-directional mode. The vehicle experiences 50 degree roll motion and leads its heading from – 70 degree to -130 degree. This position then is maintained in 10 degree of pitch position when the vehicle is maneuvered to the left.

Finally this Flight monitoring and analysis with STK is used to show RKX-EDF flight test. This flight test monitoring apparently is only used to process attitude data from RKX-EDF even though its position data can also be displayed as well. The attitude data can be described in Figure 9.

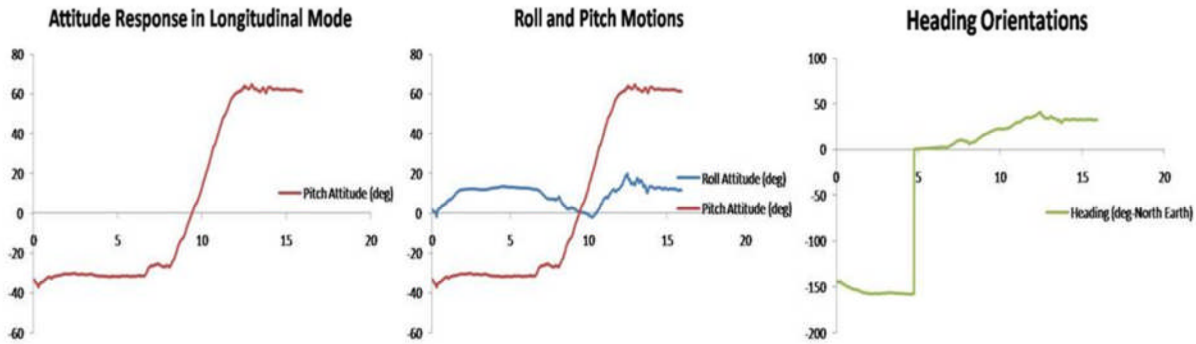

Figure9. Attitude and Heading Responses obtained from the IMU

4. Conclusions

- A flight test data monitoring and analysis has been successfully developed using Matlab and STK as core engines. The system can receive attitude and position data and visualisein grahical and 3D model in both Matlab and STK. More flight data is to be included later such as strain gagesm vibration, temperatures and pressures.
- The system can also provide comparison between physical flight test data and simulated flight test data on the same screen, and therefore enabling better understanding on the result of the flight data testing.
- More Plugin and functions can be added to enhance analysis in both Matlab and STK environment.
- Radar systems can also be incorporated in the future to supplement data from the GPS receiver.
- Matlaband STK are a good combination for live flight data monitoring and analysis, allowing rapid GUIprototyping and testing.
- Unlimited further Post-Flight data analysis can be easily performed, with the power of numerical analyis of Matlab and powerful graphical and physical system analysis of STK.

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