Autonomous Flight Safety System – Phase III

The Autonomous Flight Safety System (AFSS) is a joint KSC and Wallops Flight Facility project currently in its third phase of development. The AFSS is an independent and autonomous flight termination subsystem intended for expendable launch vehicles. It uses tracking and attitude data from onboard Global Positioning System (GPS) and Inertial Measurement Unit (IMU) sensors and configurable rule-based algorithms to make flight termination decisions.

The objectives of the AFSS are to increase capabilities by allowing launches from locations that do not have existing range safety infrastructure, reduce costs by eliminating some downrange tracking and communications assets, and increase safety by reducing the reaction time for flight termination decisions.

2005 Accomplishments

Phase III testing and development included the following accomplishments:

- Improved efficiency and accuracy of mission rule algorithms
- Expanded set of mission rule algorithms
- A data display monitor to display telemetry in real-time and archived data for post-flight analysis
- Baseline design for multiple input sensors, multiple flight processors, and redundant command switch logic and interlock circuit
- Extensive simulation testing
- Ground vehicle test
- Aircraft test
- AFSS chassis environmentally tested and ready to fly on a sounding rocket

Flight Processor Mission Rules

A full AFSS system consists of redundant chassis, each containing two independent flight processors, one internal GPS sensor and/or connections to external GPS/IMU sensors, and a command switch logic and interlock circuit responsible for initiating the firing sequence.

Each processor is loaded with the mission rules. During the flight, the data from each GPS/IMU sensor is available to each flight processor and the rocket’s current trajectory is continually checked against the mission flight rules. Each command switch logic and interlock circuit simultaneously monitors the state (Monitor/Arm/Fire) of all flight processors and initiates a destruct based on the majority vote.

The mission rule algorithms are configurable for each vehicle/mission by the responsible Range Safety authorities and can be categorized as follows:

- Rocket stage ignition and burnout detection
- Parameter Threshold Violation – a trajectory value exceeds an allowed limit
- Physical Boundary Violation – present position or instantaneous impact point is out of a corridor or in an exclusion zone
- Two-Point Gate Rule – determines if a current position or instantaneous impact point has crossed a gate formed by two points
- Moving Gate Rule – determines if the current position or instantaneous impact point is in front of or behind a moving two-point gate
- Green-Time Rule – determines how long the rocket can safely fly without receiving valid updated tracking data

Extensive testing was done using a GPS constellation simulator and launch trajectories for several different multi-stage vehicles and launch sites.

First Test on a Moving Vehicle Using Live Data

The first test on a moving vehicle using live data was also conducted. A minivan with a GPS sensor on the roof was driven around the KSC Industrial Area in a corridor that was surveyed prior to testing. The following algorithms were tested successfully:

- Parameter Threshold Violation – a speed limit was exceeded. This was a contrived but useful test for a generic parameter threshold violation.
- Physical Boundary Violation – the present position went out of the allowed region through a boundary that was not an exit gate.
- Two-Point Gate Rule – the west end of the test region was defined to be a two-point gate that could be crossed without causing a physical boundary violation.

The test and the results are described in detail in *Autonomous Flight Safety System Road Test*, KSC-YA-7738. This report has been approved for public release. To obtain a copy of the report, contact Dr. Jim Simpson at james.c.simpson@nasa.gov.

Aircraft Flight Test

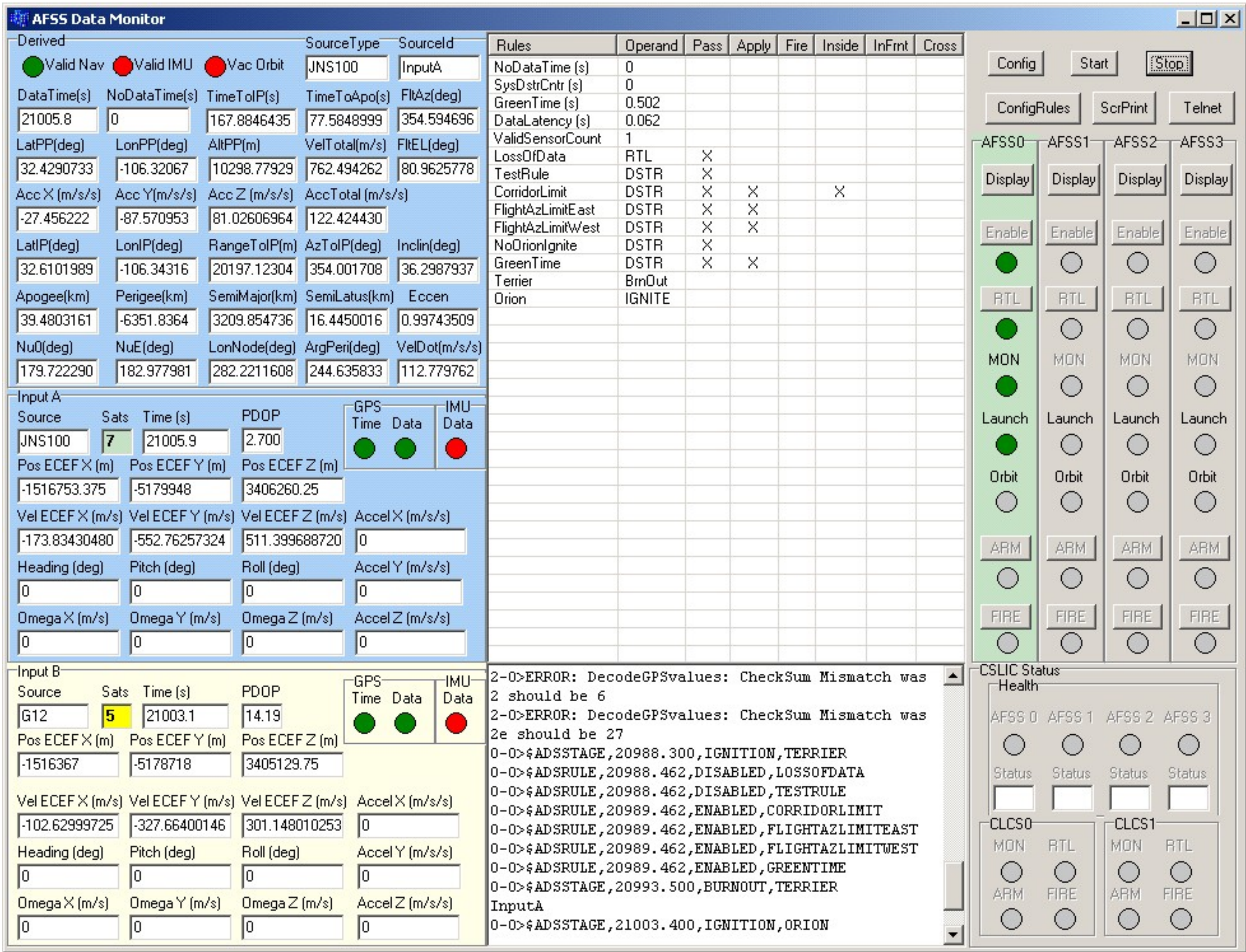
An aircraft flight took place in September 2005 on a Cherokee 235 over the St. Johns River west of KSC to test instantaneous impact point limits and three-dimensional static and moving gates. All the tests were successful and the algorithms and hardware performed as expected. The test and the results are described in detail in *Autonomous Flight Safety System September 27, 2005,* *Aircraft Test,* KSC-KT-7971. To obtain a copy of the report, contact Dr. Jim Simpson.

Sounding Rocket Flight Test

A Terrier Improved-Orion sounding rocket flight at White Sands Missile Range is currently scheduled for early 2006; however, the AFSS will not be operational and will not be connected to any pyrotechnics. Two prototype AFSS chassis based on the PC104+ platform have been built. One will be the primary flight chassis and the other will act as a backup. Each chassis has two independent flight processors, one internal GPS sensor, and connections to one external GPS sensor. One processor will be loaded with rules that *should not* destruct during a nominal flight, while the other processor will be loaded with rules that *should* destruct during a nominal flight. Both AFSS units have successfully passed the required environmental testing.

The performance of the two different GPS sensors to be used for the sounding rocket flight has already been evaluated. Using three different simulations, the navigation solutions of each receiver agreed with both the input trajectories and internal simulator truth files to within a couple of meters in position and less than a meter per second in velocity. The results gave the AFSS team confidence that both sensors will perform nominally during the sounding rocket flight. Integration of the AFSS unit with the rocket's telemetry system is underway.

A PC-based data display monitor was developed to display the GPS solutions of both GPS receivers, as well as which GPS solution is currently being used by the AFSS algorithms. The data display monitor also shows the flight rules and their current status. Other indicators display the current state of the flight processors and informational and warning text messages. An example display is shown below.



The AFSS team continues to have close contact with the range community for their input in shaping the final requirements, design, and testing of the AFSS concept. The goal is to have a flight-qualifiable unit by mid 2006 built around a rugged, compact PCI processor. More test flights are planned as vehicles become available.