Adaptive Augmenting Controller Overview

The NASA Marshall Space Flight Center (MSFC) Flight Mechanics and Analysis Division developed an Adaptive Augmenting Control (AAC) scheme for launch vehicles that improves robustness and performance by adapting an otherwise well-tuned classical control algorithm to unexpected environments or variations in vehicle dynamics.

The philosophy that drove the formulation of the AAC algorithm was first and foremost to maintain nominal system performance and be compatible with classical stability criteria. The algorithm provides additional robustness using a simple architecture that can help recover from poor performance or prevent or delay aborts in extreme off-nominal conditions.

The AAC algorithm is a forward loop gain multiplicative adaptive algorithm that modifies the total attitude control system gain in response to sensed model errors or undesirable parasitic mode resonances.

**Flight Testing of the Adaptive Augmenting Controller**

The Space Launch System (SLS) flight software prototype, including the adaptive component, was recently tested on a piloted F/A-18 aircraft at Dryden Flight Research Center (DFRC). Dryden’s advanced technology for in-flight dynamic simulation on the Full-Scale Advanced Systems Testbed (FAST) was leveraged to conduct an extensive risk reduction flight campaign. Scenarios were designed specifically to evaluate the AAC algorithm and ensure its ability to achieve the expected performance improvements with no adverse impacts in both nominal and off-nominal scenarios. Marshall developed an in-flight SLS model such that the controller “thought” it was flying SLS. 102 launch vehicle-like trajectories over six flight tests were completed in November and December 2013 at DFRC. All test objectives were successfully met and the AAC algorithm’s capability, robustness, and reproducibility have been successfully demonstrated.

**Advanced On-Orbit Guidance, Navigation, and Control**

Marshall Space Flight Center’s guidance, navigation, and control (GNC) expertise extends to the support of orbit mission operations including trajectory optimization, autonomous rendezvous and docking (AR&D), on-orbit control system algorithm design, analysis of low G propellant slosh, navigation analysis, and the development of novel and enabling guidance algorithms for emerging mission concepts such as asteroid rendezvous and autonomous on-orbit assembly. Marshall expertise is backed by a rich heritage of supporting manned orbital missions, including Apollo, Shuttle, and the International Space Station.

**Small Projects Rapid Integration & Test Environment**

The Small Projects Rapid Integration & Test Environment (SPRITE) Lab at Marshall Space Flight Center aids in the development and verification of cubesat software in a real-time, simulation environment. Engineers at SPRITE partner with universities and other third parties to provide cubesat expertise and simulation capabilities.

SPRITE has a modular, layered design that evolved from the Systems Integration Laboratory (SIL), developed for Ares I and SLS for avionics and software integration and testing. This design supports rapid reconfiguration for satellites and robotic systems. SPRITE’s plant models, algorithms, and flight software development is based on experience with the Fast, Affordable, Science & Technology Satellite (FASTSAT).

A portable version of SPRITE’s hardware-in-the-loop simulation capability has been developed. It is the result of a small project and can thus be taken to the customer’s location. In addition, the SPRITE’s hardware can be customized to meet the customer’s flight computer hardware interfaces.

**CUBESAT INTEGRATION AND TESTING**

**FLIGHT ROBOTICS LAB**

The Flight Robotics Lab (FRL) at Marshall Space Flight Center provides a full scale, integrated simulation capability for the support of the design, development, integration, validation, and operation of robotic space vehicles.

The FRL is built on developed technologies such as air bearing floors, servo drive overhead robotic simulators, precision targets, gimbals, 6 degrees-of-freedom mobility units, and a manipulator and visual system evaluation facilities. The facility is centered around a 44’ x 86’ precision air bearing floor – the largest of its kind.

Small and large air sleds are used on the air bearing floor. The air sleds hold a 400 lb. payload. An 8 DOF overhead gantry, called the Dynamic Overhead Target Simulator, provides an 800 lb. payload capability for simulating relative motion with respect to a fixed target on the facility floor. A computer system provides inverse kinematics and allows the gantry to act as either a target or as the 6 DOF rendezvous vehicle. The target reaction dynamics are simulated through force/torque feedback from sensors mounted at the payload interface.

Air bearing spacecraft simulator

Flight Robotics Lab and precision floor

Flight Robotics Lab and precision floor

Small Projects Rapid Integration & Test Environment