Adaptive Augmenting Controller Overview

The NASA Marshall Space Flight Center’s (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 parametric mode resonances.

AAC Flight Regions

\[ y = \ddot{\theta} + \dot{\theta}^2 - \dot{\theta} \dot{\phi} - (\dot{\theta}^2 - 1) \]

Adaptive Law

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 piloted 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.

Gain allocation to increase performance

NASA MSFC Full-Scale Advanced Systems Tested

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 flight 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 the Interim Cryogenic Propulsion Stage (ICPS) and the Orion Multi-Purpose Crew Vehicle (MPCV). A portable version of SPRITE’s hardware-in-the-loop simulation capability has been developed. It is in the form of a small suitcase 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.

SPRITE: Portable SPRITE Lab SIMON (SPRITE In-Air Simulation Onboard) Hardware-in-the-loop simulation

Flight Robotics Laboratory Overview

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 orbital 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 spacecraft simulator that is modeled after Apollo, Shuttle, and the International Space Station.

The facility is configured to support the design and development of a variety of robotic and navigational systems, including trajectory optimization, autonomous rendezvous and docking (AR&D), on-orbit control system algorithm design, analysis of low-cost propellant stowage, 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.