



Test trajectories flown repeatedly by NASA's F/A-18 while testing the SLS AAC.

## Testing the SLS Adaptive Augmenting Control

In 2013, a partnership of NASA organizations including MSFC, AFRC, NESC, and the Science and Technology Mission Directorate Game Changing Technology Office, conducted a series of F/A-18 research flights to test Space Launch System (SLS) prototype software, including the previously untested adaptive augmenting control (AAC) component.

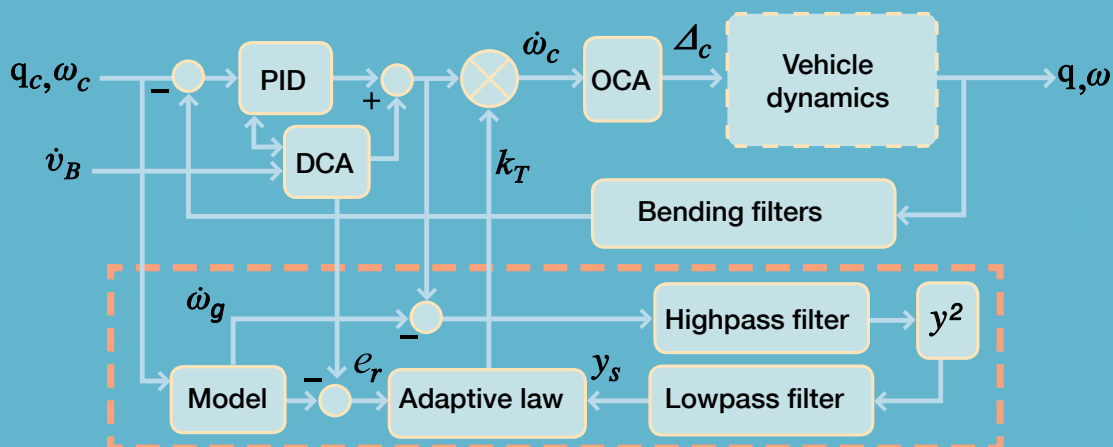
Because SLS will deliver more payload to orbit and produce more thrust than any other vehicle, past or present, it opens the way to new frontiers of space exploration as it carries the Orion Multi-Purpose Crew Vehicle, equipment, and experiments into new territories. The addition of AAC to SLS offers significant benefits to the total attitude control architecture by providing the fixed gain control architecture with additional robustness. AAC increases flight control system (FCS) performance when excessive tracking error is present and decreases responsiveness to undesirable frequency content. It expands the envelope under which the FCS is capable of safely flying the vehicle, maximizing vehicle survivability and crew safety.

If there were no vehicle or environmental uncertainty, a fixed-gain controller could be optimized prior to flight

with no need for adaptation; however, a review of historical reusable launch vehicle data from 1990 to 2002 revealed that over 40% of failures resulting from other malfunctions might have been mitigated by advanced guidance, navigation, and control technologies. Thus, an algorithmically simple, predictable AAC design with direct ties to classical stability margins was implemented for SLS. It was initially formulated and tested during the former Constellation Program, then refined as part of the baseline autopilot design and flight software prototype for SLS.

During flight testing on the F/A-18 Full-Scale Advanced Systems Testbed aircraft at AFRC, the aircraft completed a series of trajectories during multiple sorties with the SLS FCS enabled. The aircraft's pitch rate was matched to the SLS and matching attitude errors for various nominal and extreme SLS scenarios were incorporated through the use of a nonlinear dynamic inversion controller. The emphasis of the 100-plus SLS-like trajectories was on fully verifying and developing confidence in the AAC algorithm in preparation for the first uncrewed launch of SLS. □

Reference NASA/TM-2014-218528



Simplified block diagram of the SLS flight control system.