



NASA MSFC Controls Branch Current Projects

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**NASA MSFC Control Systems
Design & Analysis Branch**

Aerospace Control & Guidance Systems
Committee Meeting # 133

Asheville, NC

November 20-22, 2024

National Aeronautics and
Space Administration



**EXPLORE
MARSHALL**



Agenda

- Human Lander System
- Space Launch System
- Mars Ascent Vehicle
- Small Projects



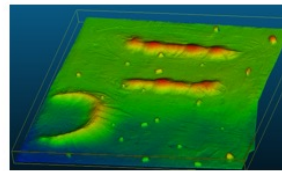
Human Lander System Risk-Based Modeling and Analysis

- MSFC Controls Branch performs targeted risk-based modeling & control system analysis to oversee SpaceX & Blue Origin Return to the Moon

Indoor Lab Provides Rapid Testing Opportunities for GN&C Algorithm Design and Eval of Moon Landing and Operations



Outdoor Rovers and Multi-Copters to design, build, and test LiDAR Hazard avoidance algorithms for autonomous nav and landing



MSFC Lunar Regolith Terrain Field

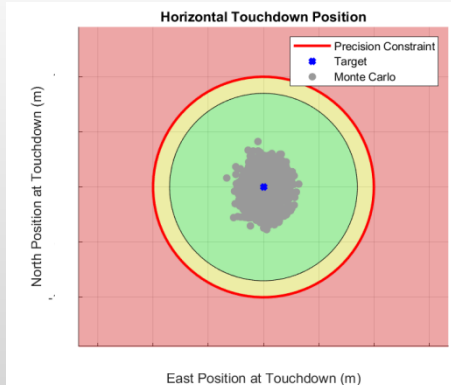


SpaceX Starship



Blue Origin's Blue Moon

Generalized Aerospace Simulation in Simulink® (GLASS) for Design and Analysis of Lander GN&C



Orphee et al. "Evaluation of Precision Landing Performance Using a Generalized Aerospace Simulation in Simulink® Framework" AAS Breckenridge 2023, AAS-23-094



Space Launch System Recent Work

➤ Booster Obsolescence & Life Extension (BOLE) TVC Actuator Model for Block 2 replaces Shuttle heritage SLS actuators with Electric-Hydraulic (EHA) System

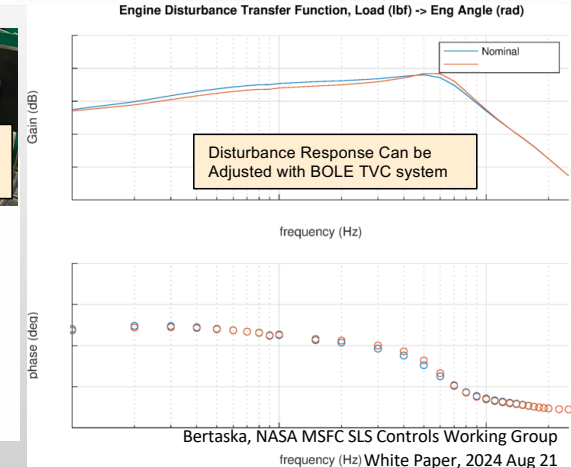
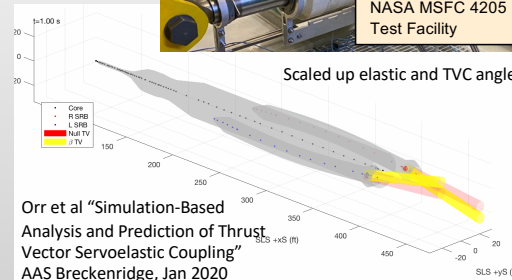
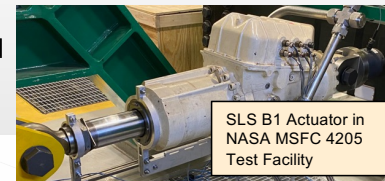
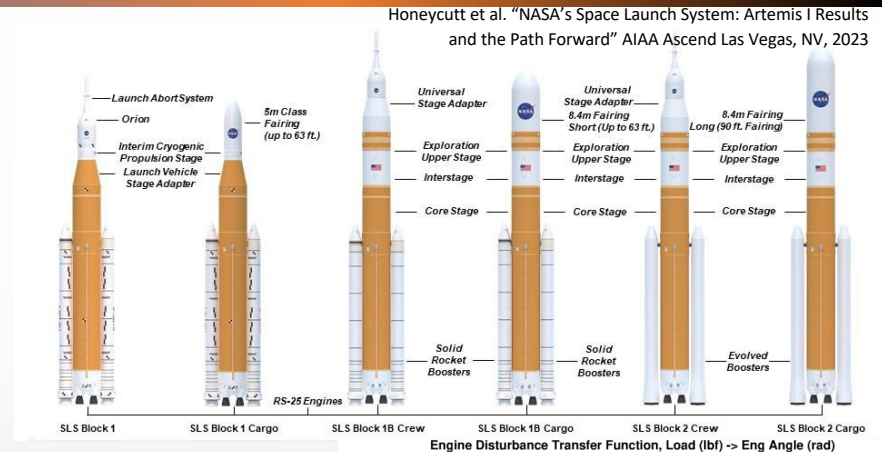
- NASA worked with vendors to develop a fully transparent model without proprietary concerns enabling NASA flight control design engineers to firmly understand the physics and implications on vehicle level coupling

➤ BOLE TVC enables Thrust Vector Servo-Elastic Resonance (TVSE) mitigation

- Feedback control adjustments were not possible on heritage TVC but the EHA enabled adjustments to increase margins against TVSE phenomena
- Balanced against as well as typical performance (GN&C driven) and stability (TVC open loop phase margins)
- Spec now contains freq response bounds for TVC external load disturbance response

➤ Manual Steering for Block 1-B for Core/EUS

- Applicable for Ascent TVC & On-Orbit RCS Phases
- Developing backup capability informed by Orion and Shuttle approaches





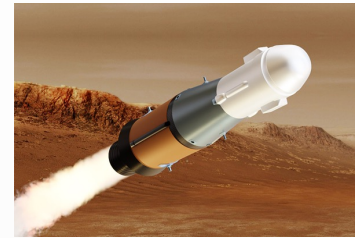
MAV Integral Methods for First Stage Control

➤ Original MAV integral logic

- gain outside the integral causes sudden change in trim when K_i is gain scheduled, transients during thrust profile

$$\dot{w}_{int} = K_i \int_{t_0}^t \theta_{err} dt$$

Multi-engine SLS vehicle with larger external disturbances (aero, engine out) allocates integral 'directly' into TVC cmds



➤ SLS integral logic

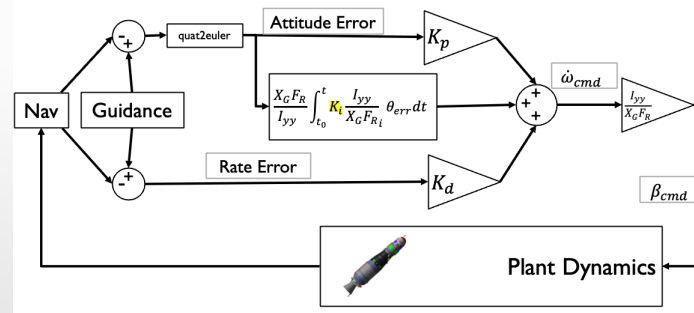
- gain inside the integral avoids "bias dump" when gain is scheduled

$$\dot{w}_{int} = \int_{t_0}^t K_i \theta_{err} dt$$

➤ MAV integral logic revised

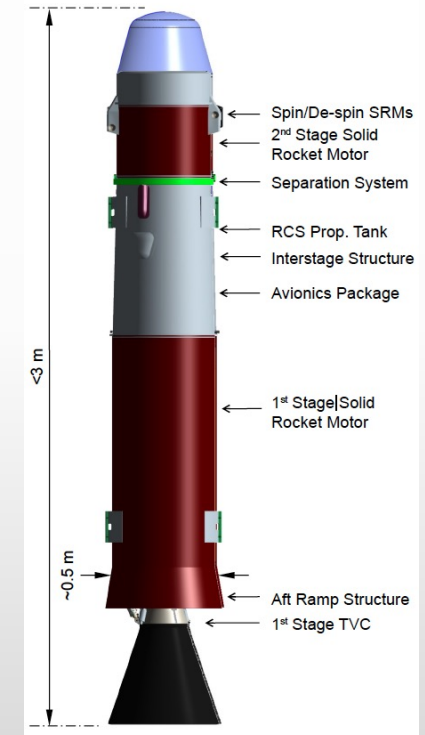
- gain & allocator inside the integral
- ensures that trim is maintained during rapid changes in solid rocket motor thrust profile by "filtering out" corresponding sudden changes in allocator gain

$$\dot{w}_{int} = \frac{X_G F_R}{I_{yy}} \int_{t_0}^t K_i \frac{I_{yy}}{X_G F_{R_i}} \theta_{err} dt$$



Russell, Colter Mars Ascent Control Working Group
TTA225 May 28, 2024

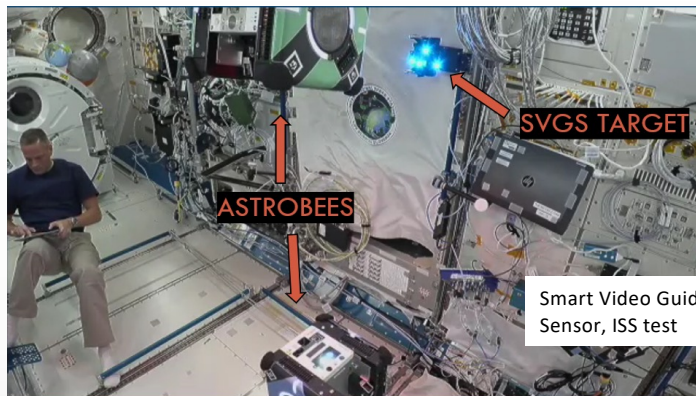
Single engine launch vehicle would lose trim against thrust vector misalignment if integral bias was directly scaled by allocator for TVC cmd -> current form enables integral to achieve longer term trim adjustments while minimizing unnecessary transients during short term thrust changes



Rountree, Yaghoubi, Maynor, Ma,
"Integrated Design for the MSR
SRC Mars Ascent Vehicle" IEEE AeroSpace
Conference March 2022

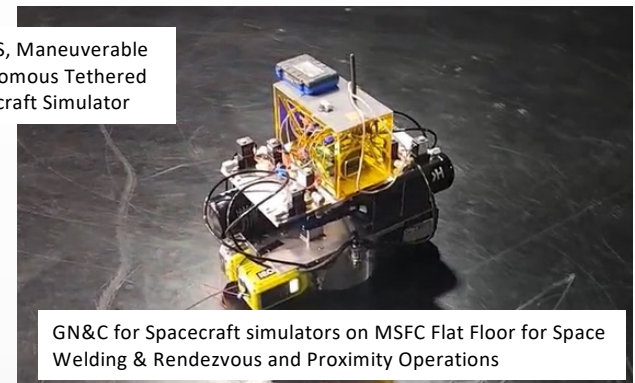


Small Projects Gallery

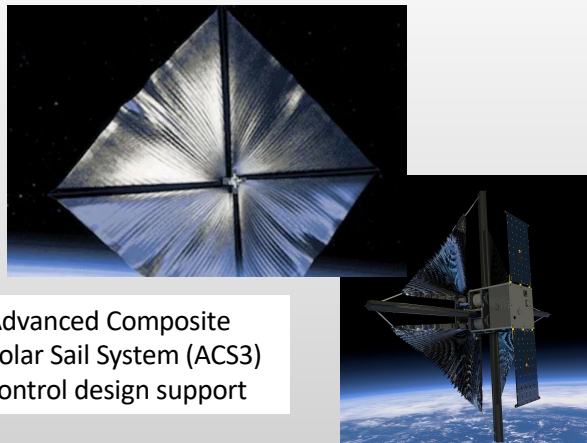


Smart Video Guidance
Sensor, ISS test

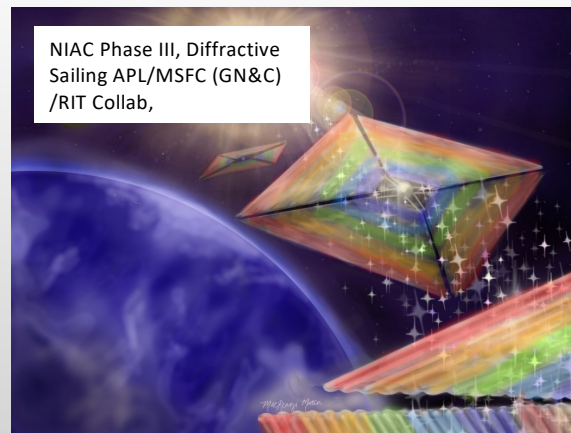
MATSS, Maneuverable
Autonomous Tethered
Spacecraft Simulator



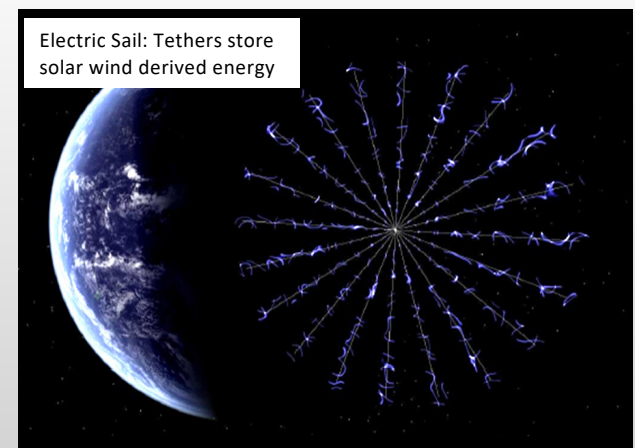
GN&C for Spacecraft simulators on MSFC Flat Floor for Space
Welding & Rendezvous and Proximity Operations



Advanced Composite
Solar Sail System (ACS3)
control design support



NIAC Phase III, Diffractive
Sailing APL/MSFC (GN&C)
/RIT Collab,



Electric Sail: Tethers store
solar wind derived energy