National Aeronautics and
Space Administration

Marshall Space Flight Center

Flight Mechanics and Analysis

The Flight Mechanics and Analysis discipline is responsible for analysis, requirements definition, design, development, and verification of Guidance, Navigation and Control (GN&C) and Integrated Systems Health Management (ISHM) and Automation systems as well as natural environments definition; this includes the GN&C and ISHM systems and supporting subsystems for both launch vehicles and spacecraft. Responsibilities include design definition as well as advancement of supporting technologies. The discipline is also responsible for the delivery of flight mechanics analysis products such as reference trajectory designs, Monte Carlo and 6-degrees-of-freedom (6-DOF) simulations, navigation, guidance, and control system designs and analyses, and modeling and simulation of other dynamic events such as liftoff clearance and stage separation. Expertise and experience are critical to exceptional performance, and the Flight Mechanics and Analysis discipline utilizes a unique tool set, many of which were developed in-house at Marshall. Those tools include the Marshall Aerospace Vehicle Representation in C (MAVERIC), the Program to Optimize Simulated Trajectories (POST), the Stability Aerospace Vehicle ANalysis Tool (SAVANT), Fractal, TREETOPS, and the Global Reference Atmospheric Model (GRAM). This discipline also has a failure detection, diagnosis, and response capability to design and validate system health management architectures and algorithms. They are also responsible for advancing the understanding and implication of relevant natural environments applicable to programs through definition, characterization, and analysis for terrestrial, space, lunar surface, and planetary environments. The discipline has developed and maintains multiple engineering support models such as the Global Reference Atmospheric Model (GRAM) Suite, Range Reference Atmospheres (RRA), Meteoroid Engineering Model (MEM), and the Lunar Meteoroid Ejecta Engineering Model (LMEEM) and conducts spacecraft charging analyses. Unique facilities for the discipline include the Automated Lunar and Meteor Observatory (ALaMO), the Natural Environments and Mission Analysis (NEMA) room in the Huntsville Operations Support Center (HOSC), the lunar regolith terrain field which simulates the lunar surface for development and testing of surface operation concepts and the System Health and Redundancy Control (SHARC) lab.


The lunar regolith terrain field at MSFC

Control Systems Design and Analysis has the responsibility to define control system architecture and control algorithms. This discipline performs requirement derivation for vehicles and subsystems and develops models to analyze vehicle performance in addition to GN&C integration. Applications include launch vehicles, pogo and slosh, spacecraft, precision pointing, solar and electrostatic sails, rovers, and landers. The Space Launch System (SLS) flight control system was designed by this group and proven during the successful launch of Artemis I. The group is also actively engaged in Artificial Intelligence/Machine Learning and advanced GN&C research and development projects, which can be tested utilizing in-house drones and simulated weightless spacecraft floating on air-bearings.

Guidance, Navigation, and Mission Analysis develops, specifies, designs, models, and verifies guidance and navigation systems for space vehicles, from small satellites to heavy-lift launch vehicles. This includes deep expertise in ascent and descent trajectory design, optimization, attitude determination and control systems, and full-vehicle simulation including both 3-DOF and 6-DOF. The discipline performs in-space orbit design, trajectory optimization, and mission analysis capabilities that span from low-Earth orbit to rendezvous and proximity operations, cis-lunar, asteroid,

Artemis I mission lifting off from the pad at Kennedy Space Center

and interplanetary missions, with extensive experience in solar sail and tether mission design and dynamics. Finally, the Guidance, Navigation, and Mission Analysis discipline provides unique Monte Carlo, multi-body 6-DOF dynamics analysis for critical events, from pad lift-off/tower clearance through all stage and component separations, and for deorbit, descent, and landing mission phases.

Integrated Systems Health Management (ISHM) and Automation provides for the understanding, design, and testing of the mission and fault management (M&FM) autonomous functionality of a vehicle or spacecraft. Mission management determines the functions for the autonomous, nominal operation of a complex vehicle or spacecraft by its flight computers in accordance with the planned mission profile and timeline. The vehicle timeline serves as an analysis tool for planned operations from prelaunch or preflight through the end of the mission based on the M&FM required functionality to operate the vehicle. Fault management determines the functions needed for fault and failure determination and response to off-nominal events in conjunction with redundancy management, safing, caution and warning, and abort conditions. From the vast set of fault management capabilities that can be monitored across the vehicle, selecting the right set requires sorting out the failures and conditions. In addition, ISHM's cradle-to-grave automation and fault management design test and verification techniques enable the mission success through end-to-end rapid development and simulation environments and integrated vehicle and mission analyses.

Natural Environments has the responsibility to define the natural environments for use in the design of launch vehicles, spacecraft, and landers, including surface payloads and habitats, to meet mission-specific performance requirements. These environments include ionizing radiation, plasma, meteoroids, neutral thermosphere, thermal environment, solar activity, atmospheric wind dynamics, surface weather, lunar meteoroid ejecta flux, and lunar and planetary environments. The agency-level Meteoroid Environment Office has the responsibility to define the hazardous meteoroid environment throughout the solar system and assist in the protection of NASA assets and crew from the associated risk.

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