National Aeronautics and Space Administration

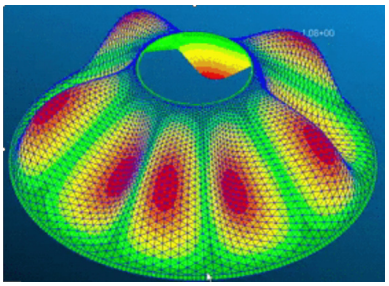
Marshall Space Flight Center

Structural Design and Analysis

Engineering the Journey

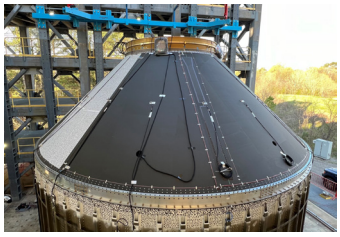
The Structural Design and Analysis team supports customers by providing structural expertise in design, analysis, and the definition of induced environments. Its key responsibility is to ensure the structural integrity of the primary and secondary structures, subsystems, and components of launch vehicles and spacecraft, including lander, transit, and habitation systems. The team's work ensures that these critical structures meet all necessary requirements and performance goals. Marshall has extensive experience in designing and analyzing launch vehicles, spacecraft, and other systems throughout all development and operational phases, including conducting forensic analysis for investigating anomalies and failures. The Structural Design and Analysis discipline includes the following specialized areas.

Structural Dynamics focuses on assessing how payloads, spacecraft, and launch vehicles respond to various operational environments. This includes conducting coupled loads analysis to define the structural loads and responses of a vehicle. The Structural Dynamics team performs analyses to assess dynamic behaviors such as aero-elasticity, propellant sloshing, and aerodynamic flutter. To predict the structural dynamic characteristics of a system, engineers employ finite element modeling and analysis (FEM/FEA). These models simulate loading events, environments, and forces, and are validated through structural dynamic testing. Additionally, the team develops criteria for random vibration, acoustic, and shock equivalent static loads, ensuring that appropriate test criteria are established for the various systems and components subjected to these environments. The Structural Dynamics team provides dynamic loads development support to customers ranging from the Space Launch System (SLS), the largest operational launch vehicle in the world, to system components and payloads both large and small.



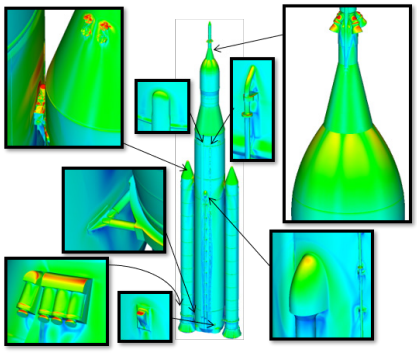
SLS Payload Adaptor Fitting (PAF) high-frequency modal response

Structural Design, Development, and Analysis encompasses the formulation, evaluation, and implementation of structural design solutions for launch vehicles and spacecraft. This discipline incorporates all requirements, including specific customer needs, industry best practices, and necessary inputs (such as loads, environments, material properties, etc.) to create a fully functional structural design solution. The design solution is verified through extensive strength analyses and, often, incremental development testing and full-scale structural qualification testing. The Marshall Structural Design and Analysis group has experience with a wide array of construction methods using both metallic and composite materials for large and small-scale structures, including cryogenics tanks, orthogrid/isogrid/sandwich/skin-stringer/truss structures, habitats, and system component design. The team can provide a variety of services, ranging from conceptual design to the delivery of flight-qualified hardware. In addition to strength and stability analysis, the team is experienced in conducting fatigue and fracture life assessments.



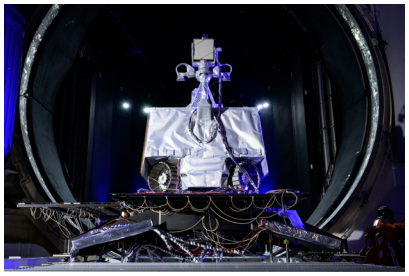
SLS PAF engineering development unit being installed in a Marshall structural test stand

Aerosciences provides launch vehicle ascent as well as stage re-entry aerodynamics and induced environments. The Aerodynamics team develops aerodynamic and aerothermodynamics design environments for applications that range from subsonic to hypersonic flight regimes. Experience includes complex multi-phase, fully reacting computational fluid dynamics (CFD) analyses and empirical solutions with an emphasis on applying the appropriate level of fidelity to each unique problem. Marshall has code developers for several industry-standard aerodynamic heating and plume flow field analysis tools. Extensive aerodynamics and induced environments test experience resides in-house, including primary test engineers for the 14-inch tri-sonic wind tunnel at Marshall. The team also performs launch vehicle debris transport and impact analyses, launch vehicle off-nominal blast, debris fragment modeling, and has supported a wide range of explosive blast test programs with dynamic pressure measurements, high-speed imaging, and debris collection and classification. The Aerosciences discipline also includes the conduction of applied research in areas such as plume-surface interactions (PSI).



Aerodynamic heating on the SLS during ascent

Thermal Analysis and Control is responsible for the thermal management and protection of spacecraft, vehicles, payloads, and related hardware through all prescribed mission phases. The team provides analytical predictions to support both the thermal control and thermal protection system design processes. Using specialized computational tools, the team can model steady-state and transient multi-mode heat transfer and fluid flow in terrestrial, ascent, orbital, and inter-planetary environments. The team also has extensive thermal testing experience and capabilities and can provide both development and qualification test planning, execution, real-time support, data reduction, and model correlation.



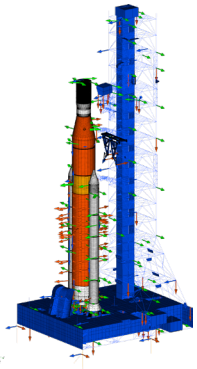
Thermal vacuum (TVAC) testing of the Volatiles Investigating Polar Exploration Rover (VIPER)

Capabilities

Structural Dynamics

Expertise includes:

- Integrated coupled loads analysis for prelaunch, ascent, in-space, and docking
- Shock and vibroacoustic environment definition
- Slosh analysis and baffle design
- Finite element modeling
- Structural dynamics pre-test analysis and test optimization
- Tools: Next-Generation NASA STructure ANalysis (NX NASTRAN) and Multidisciplinary Structure Analysis (MSC) NASTRAN, Finite Element Modeling and Post-processing (Femap) and PATRAN, Python, LS-DYNA and LS-OPT, Matrix Laboratory (MATLAB), VAOne, Wave6, Integrated Multidisciplinary Analysis Tool (IMAT), and Attune.

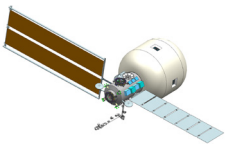


SLS and mobile launcher finite element model of the integrated modal test (IMT) configuration with response transducers depicted by arrows

Structural Design, Development, and Analysis

Expertise includes:

- Structures/subsystem/component design and integration
- Metallic and composite materials
- Finite element modeling and analysis
- Structural sizing and strength analysis
- Stability/buckling analysis
- Fracture and fatigue life prediction
- Static structural test definition
- Tools: CREO, NX, SpaceClaim, HyperSizer, MATLAB, Femap, NASTRAN, PATRAN, Abaqus, NASGRO

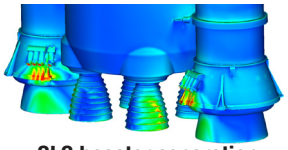


NASA reference design configuration of the Mars Transit Habitat

Aerosciences

Expertise includes:

- Aerodynamics databases and loads
- Aeroacoustic and compartment venting environments
- Aerodynamic heating, plume flow field characterization, impingement, radiation, and convective heating environments



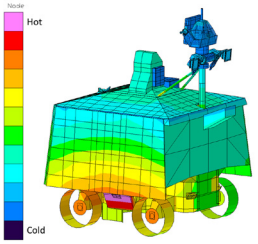
SLS booster separation motor plume impingement heating

- Plume-surface interaction analysis and surface crater reconstruction
- Blast wave, fragmentation, and ascent/liftoff debris impact modeling and testing
- Tools: Loci/CHEM, MINIVER, RAMP, GRAD, RMC, Plume Impingement Program (PLIMP), CHCHVENT, LS-DYNA, LFOAM, SFOAM, ANSA, Pointwise, Tecplot, STAR-CCM+, Cart 3D, MATLAB.

Thermal Analysis and Control

Expertise includes:

- Thermal design and analysis for ground, ascent, orbital, and re-entry environments
- Thermal protection sizing for insulators and ablatives
- Ice formation prediction
- Multilayer insulation, heaters, and active thermal control design and analysis, including heat pipes, heater/thermostats, forced convection, cold plates/pumped loop
- Tools: Thermal Desktop, Surf Ice, System Improved Numerical Differencing Analyzer/Fluid Integrator (SINDA/FLUINT), SINDA/G, COMSOL, SpaceClaim.



Temperature contour plot of the Volatiles Investigating Polar Exploration Rover (VIPER) thermal analysis performed by Marshall

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Marshall Space Flight Center
Huntsville, AL 35812
www.nasa.gov/center/marshall

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