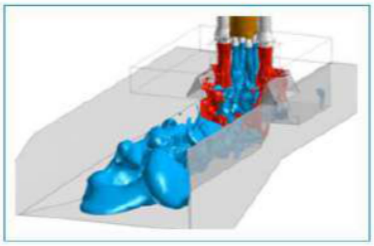
Reaching Beyond Low Earth Orbit

Complex launch environment simulations enabled by NASA supercomputers are advancing the design of the Space Launch System, long before its ignition and liftoff.

The Space Launch System (SLS), NASA's first exploration-class vehicle since the Saturn V launched the Apollo astronauts to the Moon, is shaping up to be the most powerful rocket in history. Designed to be flexible for crew or cargo missions, the SLS will carry the Orion Multi-Purpose Crew Vehicle as well as heavy payload to deep-space destinations such as near-Earth asteroids, the Moon, and, ultimately, Mars.

Engineers face many design challenges as they prepare for the first SLS flight, scheduled for the end of 2017. Among them is that the SLS will produce 10 to 20% more thrust than the Saturn V — depending on whether it carries crew or cargo — and will require an entirely new launch environment at Kennedy Space Center in Florida. NASA's computational fluid dynamics (CFD) researchers have developed new models to simulate the launch conditions for a variety of potential vehicle designs and run them on an agency supercomputer.



"Modeling and simulation methods developed for the Space Shuttle Program aren't able to accurately model the complex conditions for the SLS configurations," said Gabriel Putnam, CFD researcher in the Fluid Dynamics Branch at NASA's Marshall Space Flight Center (MSFC), Huntsville, Ala. "We really had to step up our tools development effort to help meet these new design challenges."

One of these challenges is mitigating ignition overpressure (IOP) waves — acoustic pressure waves generated at liftoff by ignition of the vehicle's solid rocket boosters. These large-amplitude pressure waves radiate throughout the launch environment and, if not fully understood and carefully planned for, can cause catastrophic damage to the vehicle, the launch pad, and the payload.

Using thousands of processors on the Pleiades supercomputer at the NASA Advanced Supercomputing Division (NAS) at Ames Research Center, Moffett Field, Calif., the MSFC Fluid Dynamics team ran more than 40 CFD simulations, each spanning several weeks and requiring multiple terabytes of storage to process hundreds of individual gigabyte-scale files for visualization, post-processing, and data analysis. These simulations capture the sources of the acoustic waves and follow the action to track their effects throughout the launch environment. Validated results are provided to SLS engineers so they can optimize the design of the vehicle and launch components, including:

- Launch pad geometry — Complex launch configurations include surface topology, flame holes, sub-pad flame trenches, and other integral components that can be designed and combined in a variety of ways. CFD modeling of possible launch environments helps designers determine the most effective formats well before construction begins.
- Sound suppression techniques — Traditionally, water-suppression methods have been used to dampen IOP waves enough to allow spacecraft to launch safely. These methods involve injecting hundreds of thousands of gallons of water into the trenches beneath the launch pad. The CFD simulations provided by Putnam's team offer data that can help designers target the placement of water injection systems for specific SLS configurations.

Validation of the team's early simulation findings with real-world test results provided NASA with the confidence to move forward with CFD simulations of the full-scale, dynamic, integrated system that will comprise the SLS launch environment. These high-fidelity, state-of-the-art CFD tools, made possible by NASA's supercomputing capabilities, are providing the foundational data that will ensure the best possible vehicles for deep space exploration that carry humans beyond where we have gone before.

Related SC12 Demos

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- Validating Water Spray Simulation Models for the SLS Launch Environment
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More Information:

- Space Launch System
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- SLS Fact Sheet (PDF - 196KB)
- SLS Fun Facts (PDF - 1.7MB)
- Pleiades Supercomputer