Keeping Astronauts Safe

Predicting Vibrations on the Launch Abort Vehicle

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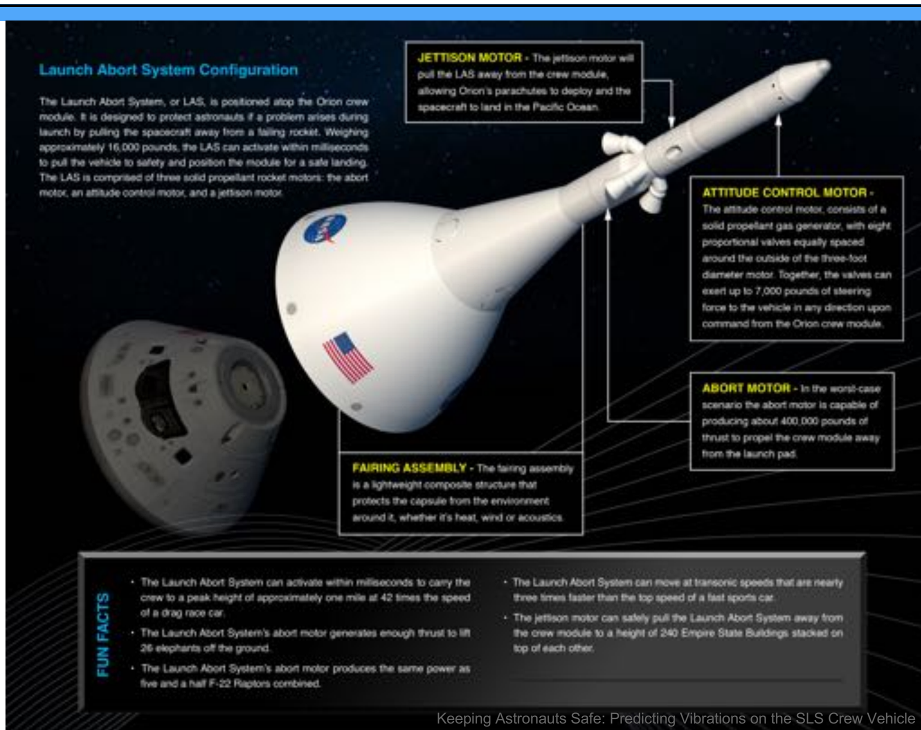


ST1 Launch Abort Motor Test

QM1 Launch Abort Motor Test

Qualify LAS solid rocket motors for flight

Performed turbulence-resolving computational fluid dynamics (CFD) simulations

Slow motion video from ignition to 0.3 seconds

Rendering of QM1 test simulation with isosurfaces of Q-criterion colored by gauge pressure

Using HPC To Keep Astronauts Safe

Perform time-resolved CFD simulations to predict transient pressure loads on heat shield and crane ahead of QM1 test to ensure test safety

Use comparison to ST1 and QM1 measurements to validate Launch, Ascent and Vehicle Aerodynamics (LAVA) simulation software

Simulation details:

- LAVA solves full non-linear Navier-Stokes coupled partial differential equations
- 350 million degrees of freedom in space, clustered automatically in most important regions
- Integrated in time ~1 microsecond at a time from ignition to 0.3 seconds
- Massively parallel simulations on 50-80 Intel Broadwell nodes for a total of 2000+ cores
- Completed in ~40 days on NASA’s Pleiades Supercomputer
- Generates ~100 Terabytes of data

QM1 Launch Abort Motor Test

Slow motion video from ignition to 0.3 seconds

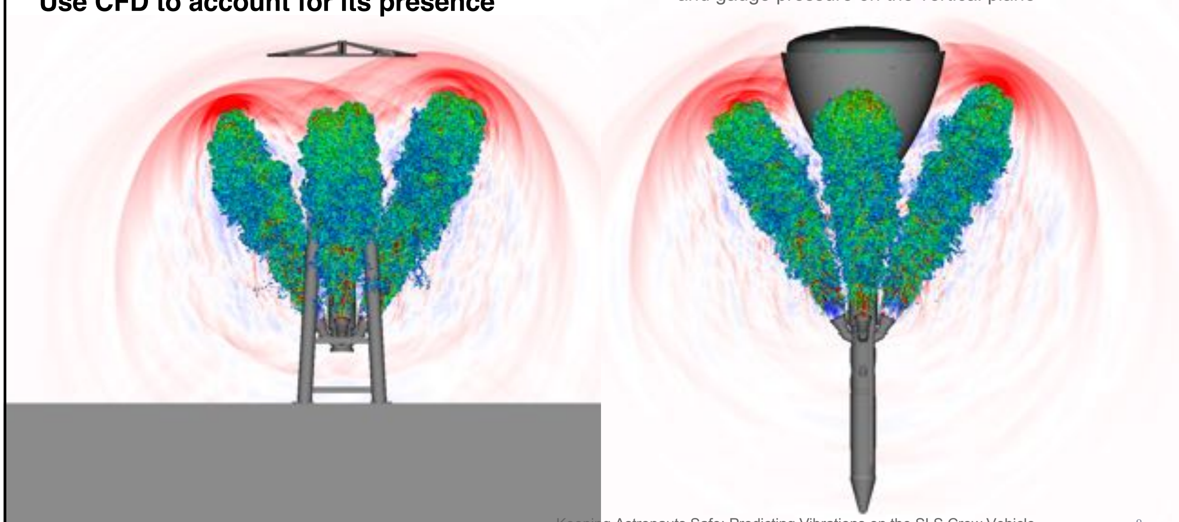
Rendering of QM1 test simulation with passive particles seeded at the nozzles colored by Mach number and gauge pressure on the vertical plane

Launch Abort Vehicle Simulations

LAV was missing from QM1 test

Use CFD to account for its presence

Renderings of QM1 test and LAV pad abort simulations with isosurfaces of Q-criterion colored by Mach number and gauge pressure on the vertical plane



Launch Abort Scenario

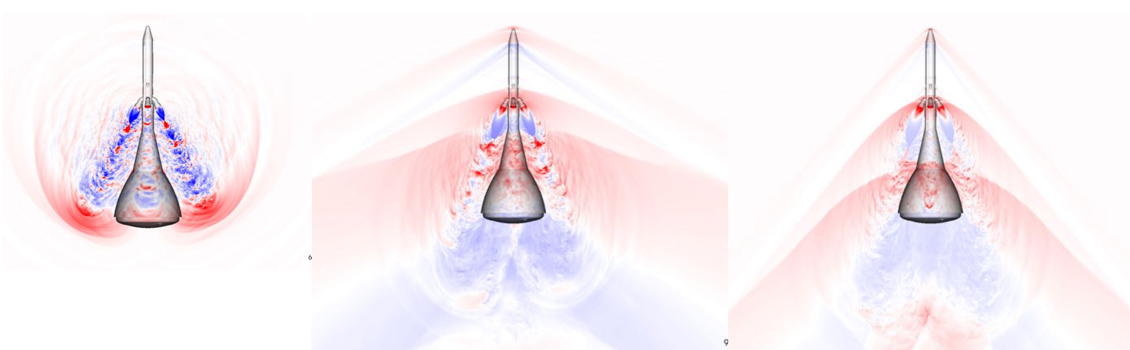
Rendering of LAV launch abort simulation with isosurfaces of Q-criterion colored by gauge pressure

Slow motion video from ignition to 0.3 seconds

Ascent Abort Scenarios

Launch abort can also happen during ascent

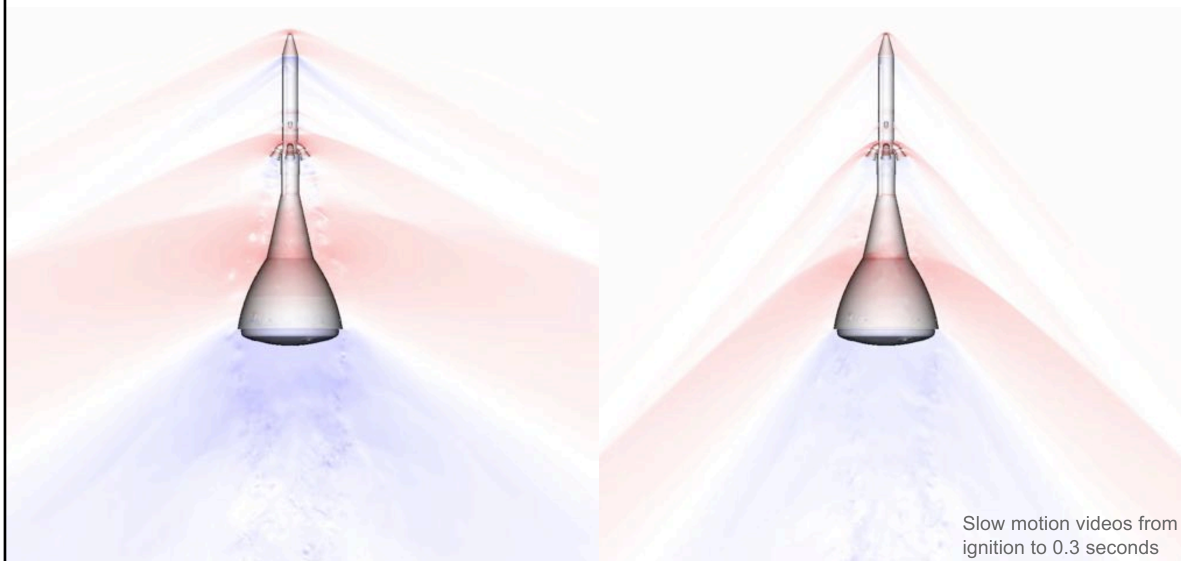
Use CFD to identify differences in transient loads, hot spot locations



Gauge pressure on the vertical plane and on the LAV surface for launch (left), transonic (middle), and supersonic (right) abort scenarios

Ascent Abort Scenarios

Gauge pressure on the vertical plane and on the LAV surface transonic (left), and supersonic (right) ascent abort scenarios



Slow motion videos from ignition to 0.3 seconds

Ascent Abort Scenarios

Rendering of LAV transonic ascent abort simulation with isosurfaces of Q-criterion colored by gauge pressure

Slow motion video from ignition to 0.3 seconds

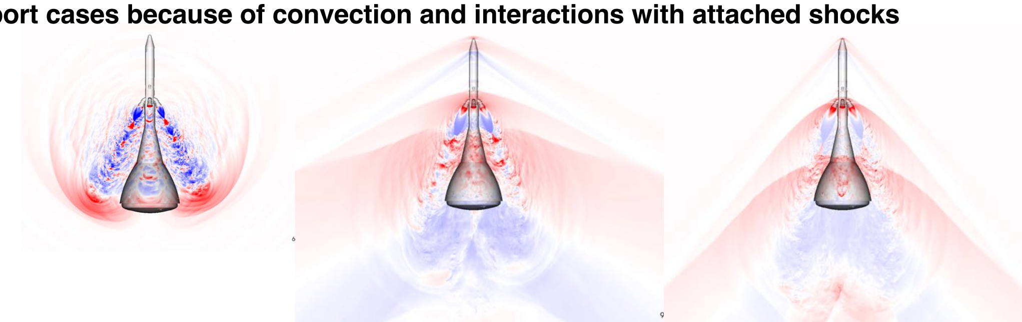
Ascent Abort Scenarios

Results & Impact

Validated computational aero-acoustic prediction capabilities for LAVA software

Discovered that pressure doubling on the surface only occurs near the nozzle due to the change in incidence angle → vibrations are not as strong as expected on LAV

Showed how vibration hot spots move and overall vibration levels are reduced on ascent abort cases because of convection and interactions with attached shocks



Why HPC Matters

The availability of the rich dataset from our many simulations directly impacts the final design for the SLS launch abort vehicle

NASA Advanced Supercomputing (NAS) facility's visualization experts provided passive particle renderings that helped enrich our understanding of the fluid dynamics in the plume of the launch abort motors

Ongoing effort to reduce uncertainty in transient loads on LAV by simulating cases outside of nominal operations

Resources

For more information on the LAVA computational framework, please refer to this paper:

Kiris, Cetin C., et al. "Computational framework for launch, ascent, and vehicle aerodynamics (LAVA)." *Aerospace Science and Technology* 55 (2016): 189-219.

For more information on the Space Launch System:

https://www.nasa.gov/exploration/systems/sls/index.html

For the official Orbital ATK video of the QM1 launch abort motor test, please follow this link: https://www.youtube.com/watch?v=B-1qajOvEI4