# Predicting Orion Launch Abort Acoustics

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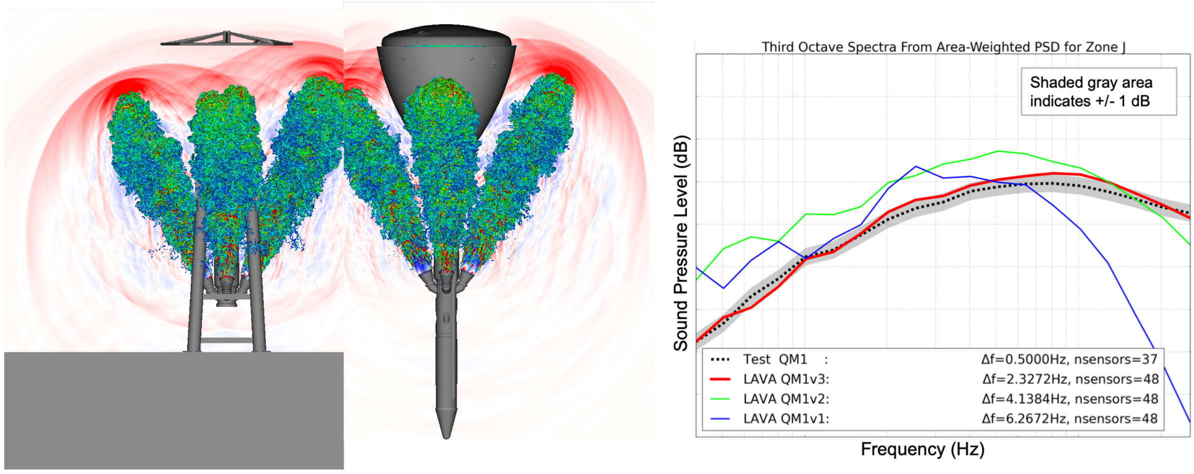
**Abstract:** NASA's Artemis Program aims to transport humans to interplanetary destinations such as the Moon – and eventually Mars – and return them safely back to Earth via the Orion crew module. During launch, Orion will sit atop the Space Launch System (SLS) rocket and will be outfitted with a Launch Abort System (LAS). The LAS is designed to carry the spacecraft and its crew to safety, away from the rocket, in the event of a problem during launch. The LAS is positioned on top of Orion during takeoff and jettisoned once it has safely reached low-Earth orbit. In order to propel the crew module away to safety, the LAS uses an abort motor that produces four large high-speed exhaust plumes that flow along the sides of Orion, generating extremely strong pressure fluctuations on the vehicle's surface. These vibrations need to be carefully analyzed to ensure the safety of the astronauts. A collaborative effort with the Orion Loads and Dynamics team at Johnson Space Center aims to help characterize the vibrations imparted by the LAS abort motor plumes onto the LAS structure with detailed scale-resolving simulations. Various launch abort scenarios were simulated using the Cartesian AMR Navier-Stokes solver in the Launch, Ascent, and Vehicle Aerodynamics (LAVA) computational fluid dynamics (CFD) software [1]. Best practices developed using the Qualification Motor 1 (QM1) ground test will be detailed: mesh generation, numerical method, data collection, post-processing. Figure 1a demonstrates the level of fine turbulent structures and pressure waves resolved. The third octave spectra of various sensors in the ground test are compared to CFD to validate the predictions. Figure 1b shows the excellent agreement obtained with ground test measurements for the heat shield sensors. The methodology is extended to the Orion LAS for pad abort, and ascent abort scenarios with an eye toward flight tests for further validation. We simulated the Pad Abort 1 (PA1) flight test conducted in 2010 to study the effect of acceleration on the vibro-acoustic environment – see figure 2 – and different segments of the Ascent Abort flight test (AA-2) conducted in 2019 to investigate the effects of altitude and Mach number. Every effort will be made to make meaningful comparisons in terms of $\Delta$dB and non-dimensional frequencies between CFD and available measurements, given that all data related to this project is protected under the International Traffic in Arms Regulations (ITAR).

*Keywords:* Computational Fluid Dynamics, Aeroacoustics, Cartesian Grid Methods, Adaptive Mesh Refinement, Immersed Boundaries.




(a) (b)

Figure 1: (a) Snapshot of isosurfaces of Q-Criterion colored by Mach number, along with gauge pressure on the vertical plane (blue is low, red is high). Left: QM1 ground test simulation. Right: Equivalent simulation with the Orion Launch Abort Vehicle. (b) Area-averaged third octave spectra for the heat-shield sensors in QM1 ground test (black dashed line) and LAVA CFD predictions as best practices were improved from QM1v1 to QM1v3.

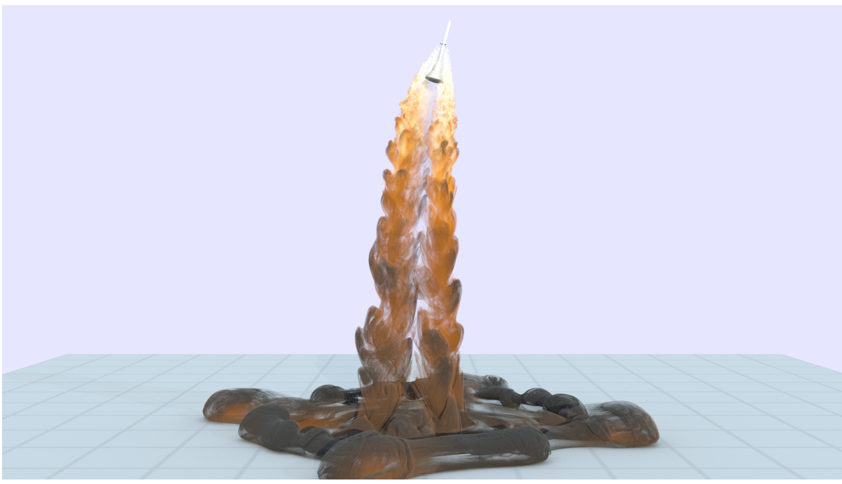


Figure 2: Snapshot from PA1 simulation showing passive particles colored by velocity magnitude (white is high, dark orange is low) seeded at the nozzle exit. A blue tile pattern is used to indicate the position of the ground.

# References

[1] C. Kiris, J. Housman, M. Barad, C. Brehm, E. Sozer, and S. Moini-Yekta. Computational Framework for Launch, Ascent, and Vehicle Aerodynamics (LAVA). *Aerospace Science and Technology*, 55:189–219, 2016.