Review of Aeroacoustic Prediction Techniques for Launch Vehicles

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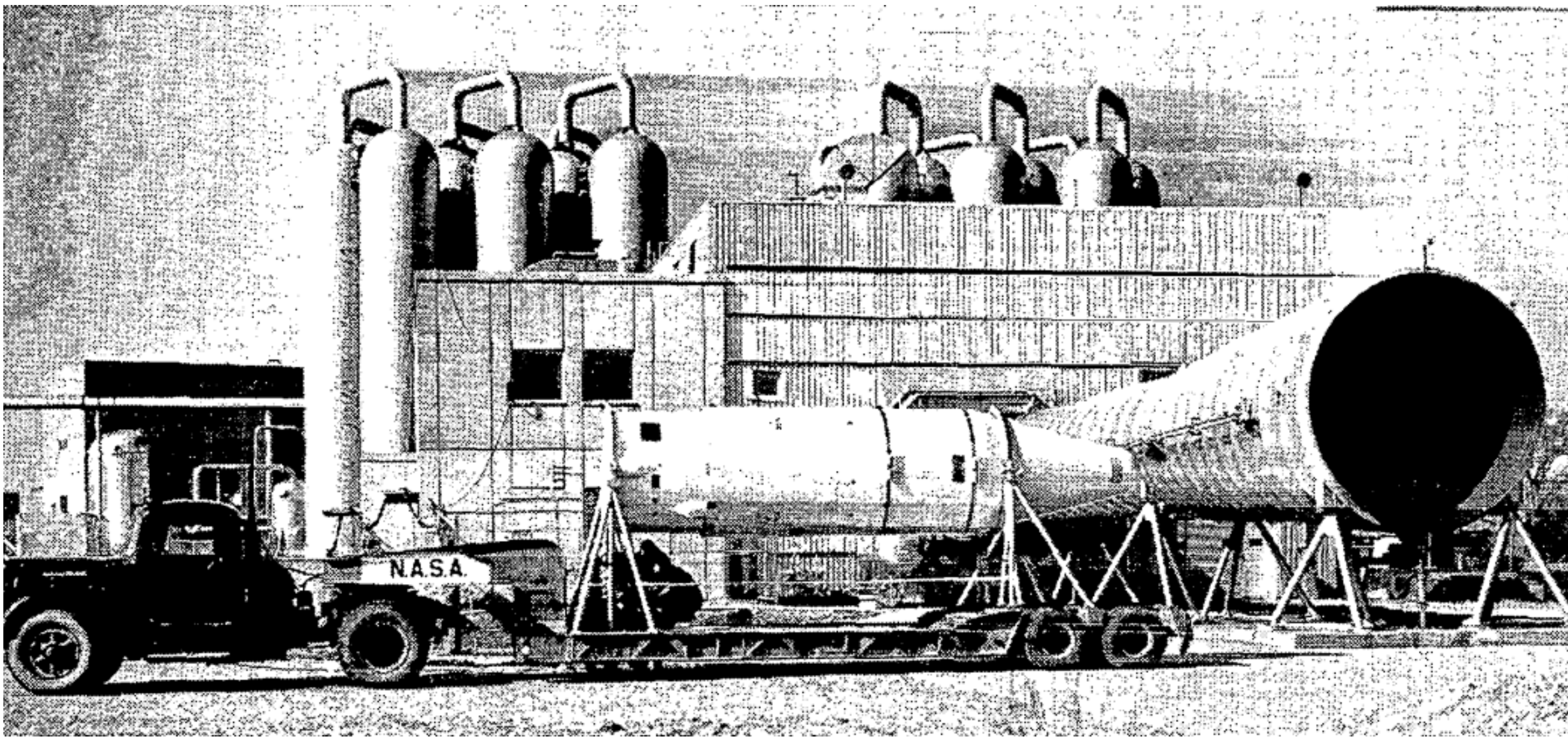
Motivation

- Launch vehicles experience severe acoustic environments
  - Launch: engine plumes reflected by pad
  - Ascent: Transonic flight, unsteady shocks, engine plume noise
  - Abort: Direct abort motor plume impingement/flow interaction
- Potential hazards due to structural vibration
  - Failure of electrical or mechanical component
  - Fatigue failure of internal or exterior structural component
  - Fatigue of payload
- Goal: design to minimize acoustics
- Need methods of modeling aeroacoustics

Free-Field Acoustic Testing

- Subject test article to unconstrained acoustic source
  - Need acoustic source similar to flight
    - Blowdown wind tunnel exhaust
    - Rocket engine static test

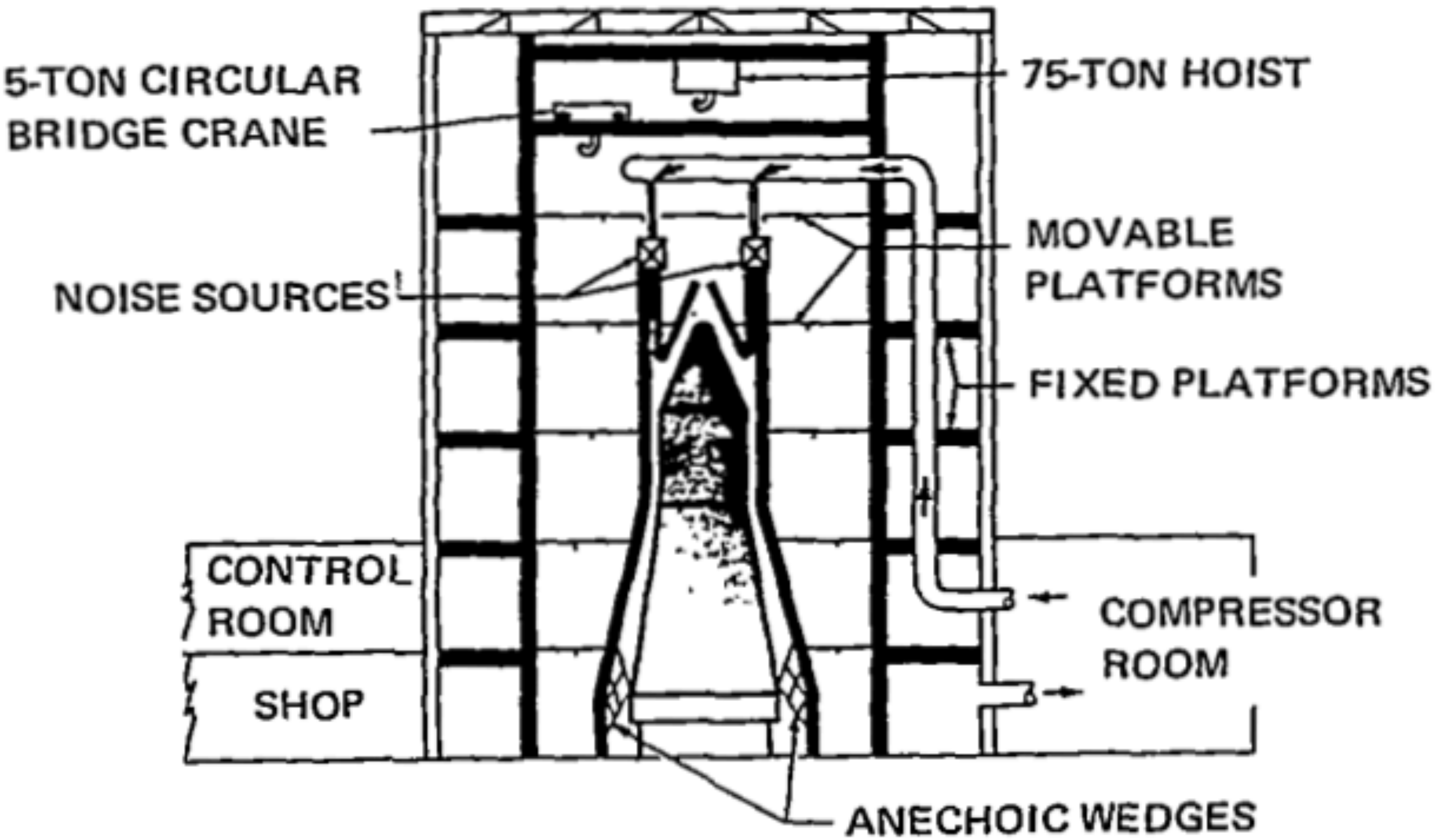


Reverberant Acoustic Testing

- Chamber surrounded by noise-producing horns

Progressive Wave Test

- Chamber connected to outside with many ducts
  - Acoustic source outside
  - Control source individually in each duct

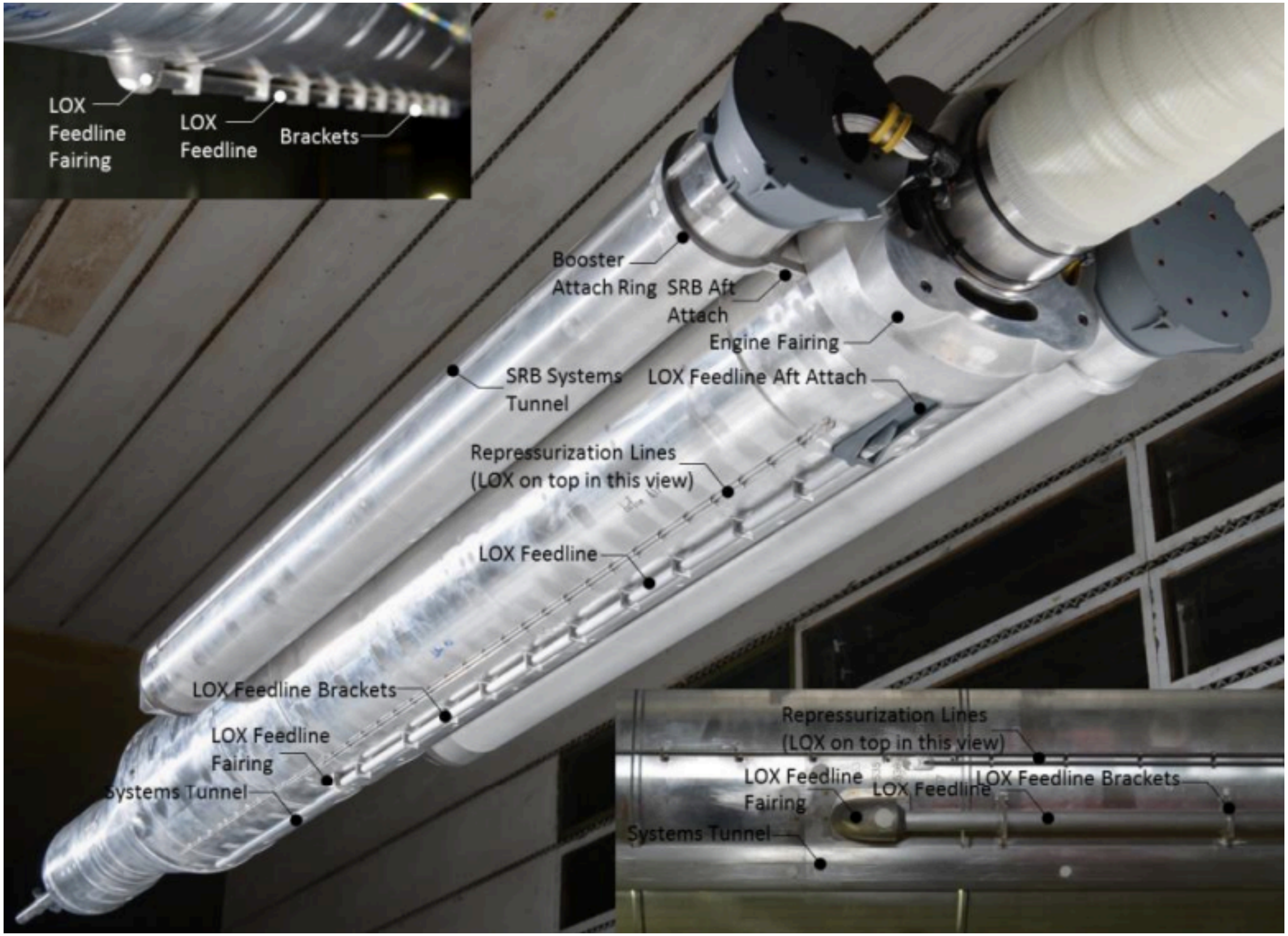


Flight Testing

- Full-scale flight test with pressure transducers on vehicle
- Microphone Phased-Array
  - Determine source strength/location accurately from distance

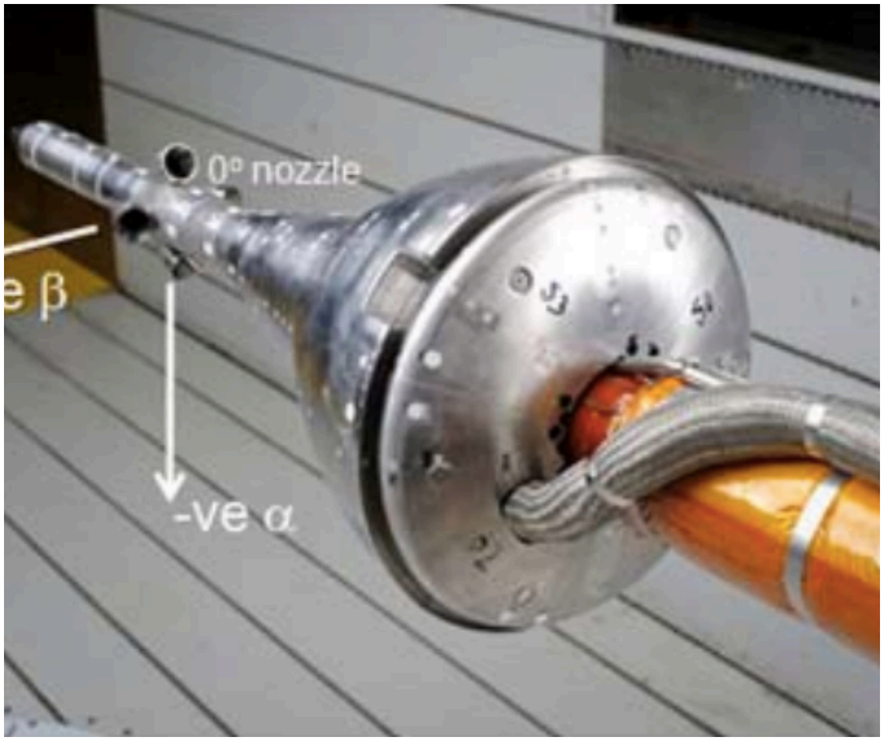
Wind Tunnel - Ascent

- Subscale models in scaled flow
  - Modern manufacturing techniques produce high-fidelity models



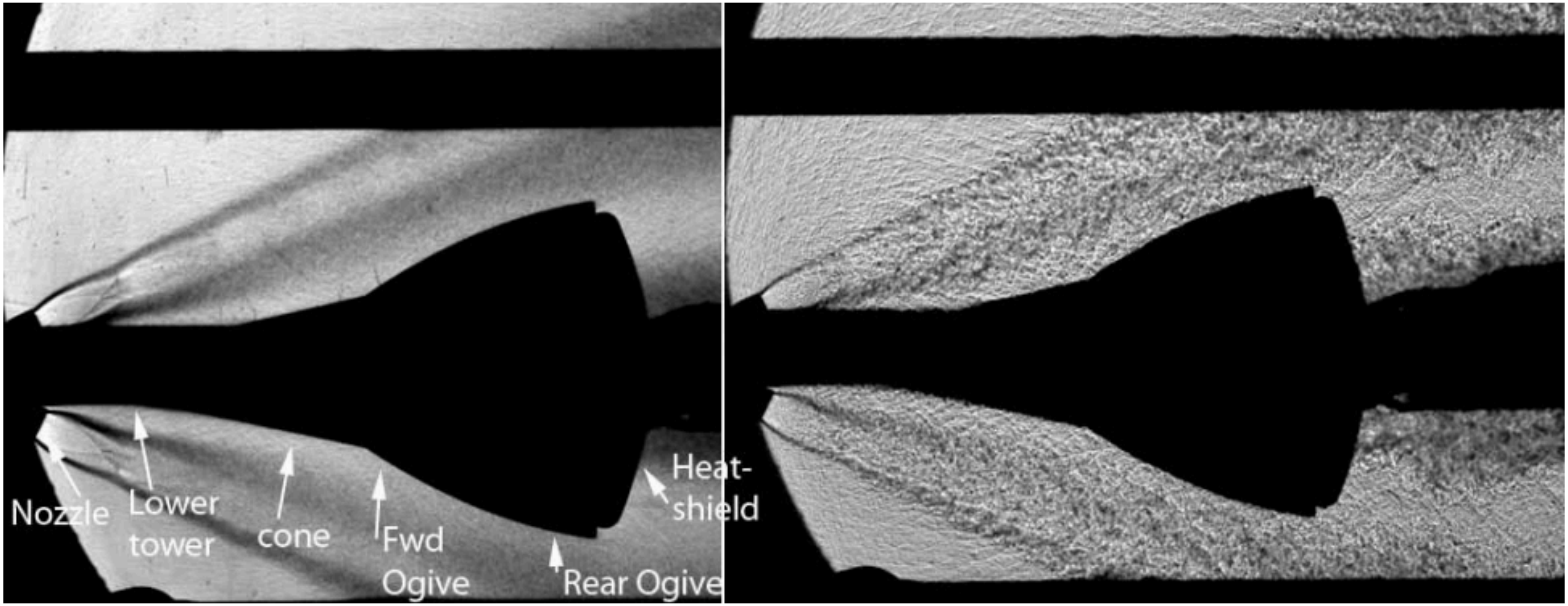
Wind Tunnel - Abort

- Use heated Helium to simulate rocket motor plumes



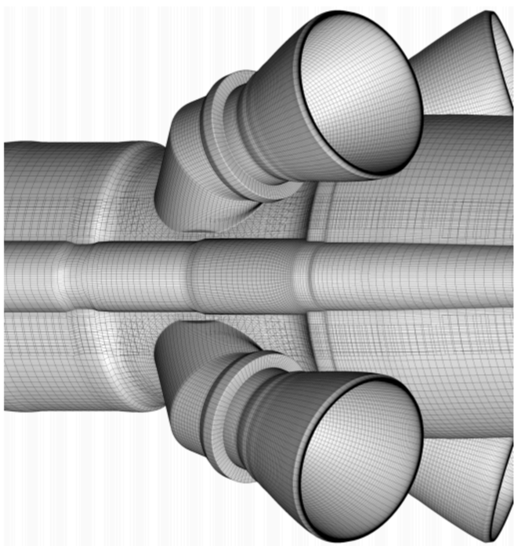
Wind Tunnel - Abort

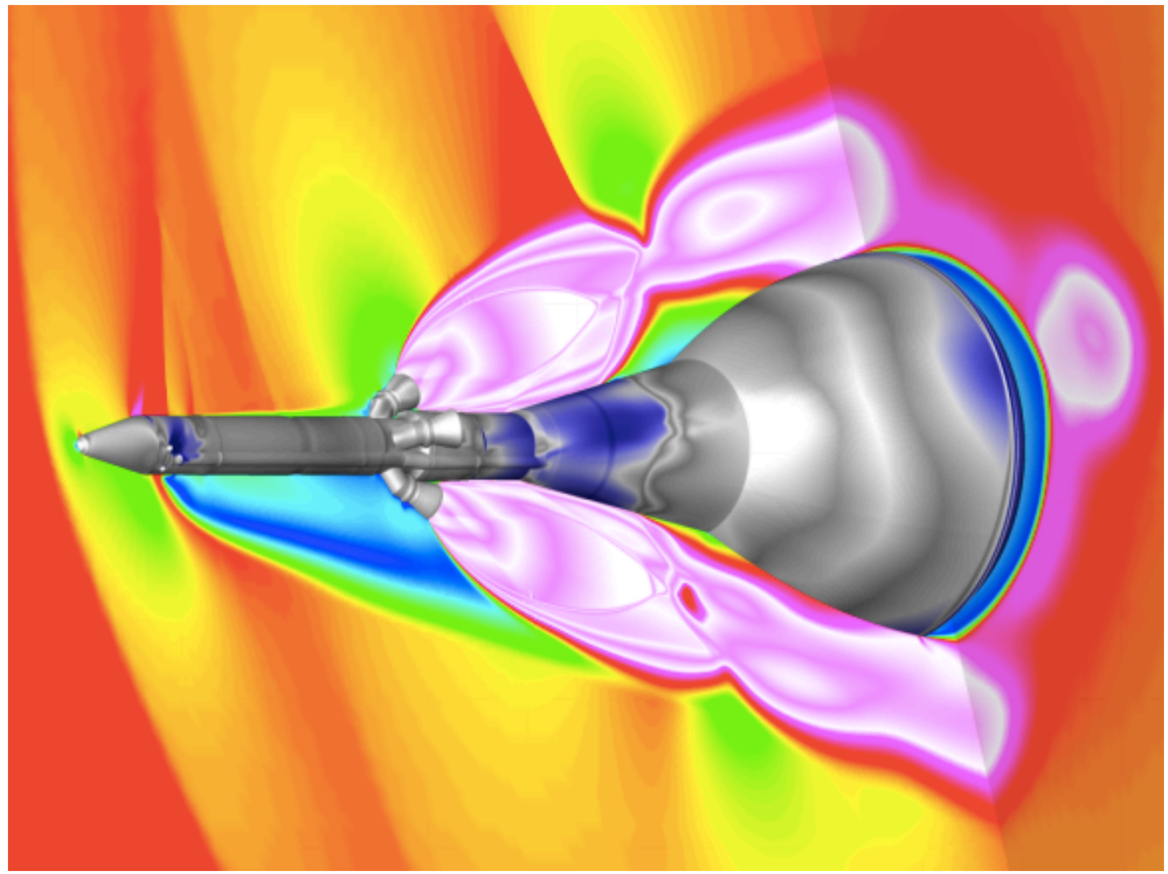
- Complex aeroacoustic effects



Computational Fluid Dynamics

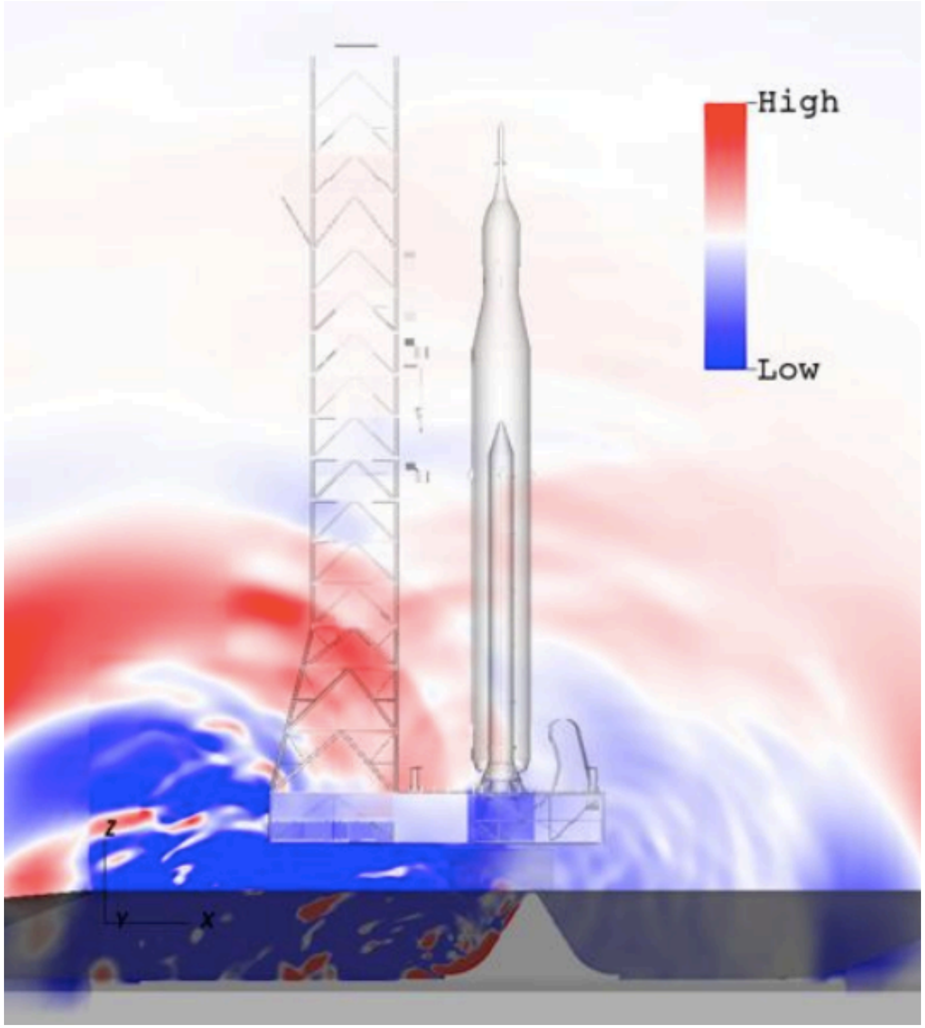
- Can resolve unsteady flow for high-fidelity geometry
  - Fraction of cost of wind tunnel
  - Not sophisticated enough for aeroacoustics





Computational Aero-Acoustics

- Couple CFD/CAA solvers to produce acoustic results
  - LAVA solver (Development still needed)



Conclusions

- All discussed methods are uniquely useful
  - Flight test: can’t beat the real thing
  - Wind tunnel: much cheaper than flight and still accurate but…
  - CFD/CAA: Even cheaper! (but less accurate, needs validation data ↑)
  - Acoustic testing: structures must be able to survive vibration

- The future
  - Computational methods will improve, become more ubiquitous
  - Experimental methods will always be required to check computational