Space Shuttle and Launch Pad Lift-Off Debris Transport Analysis – SRB Plume-Driven

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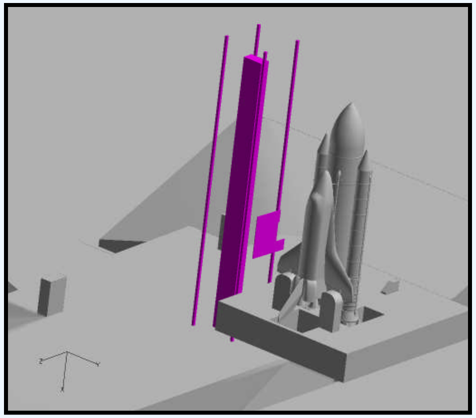

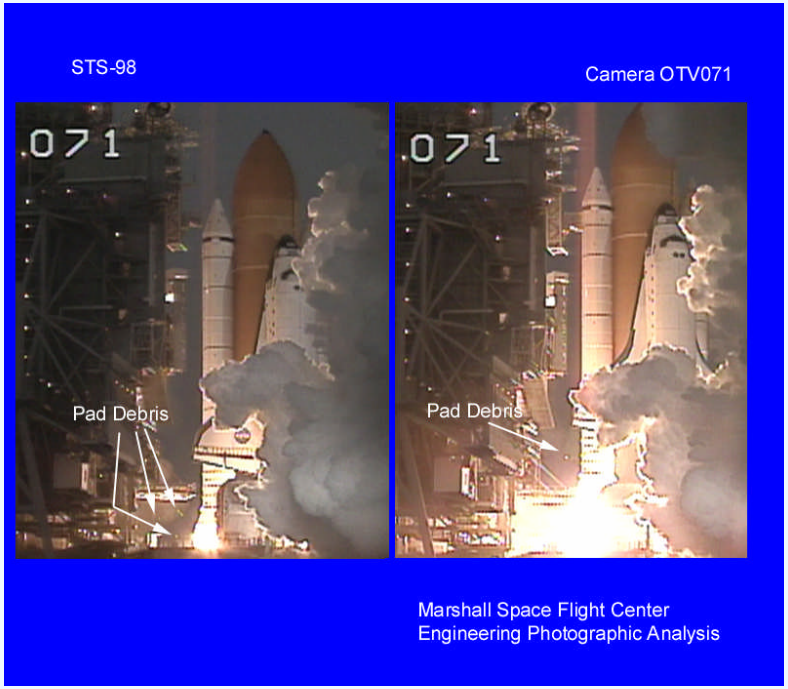

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Lift-Off Debris Transport Analysis

Need: **Determine the possible size, speed, impact location, and impact energy of potential debris.**

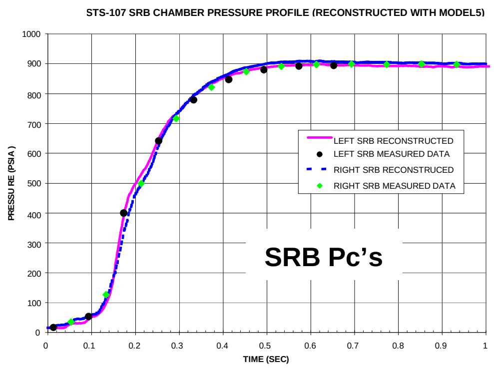
Approach:

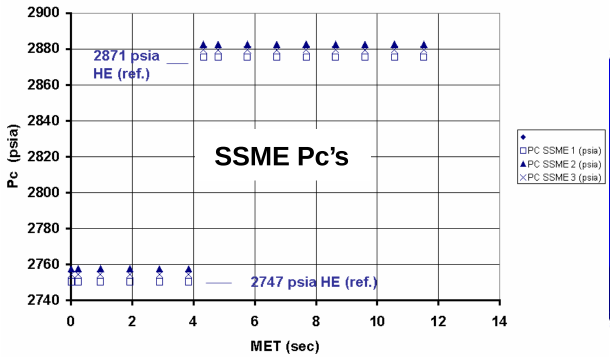
1. **Use computational fluid dynamics (CFD) techniques with debris trajectory tracking tools to analyze potential debris events:**
    - simulate Ground winds, gravity, and the Shuttle plume flow interactions with the Launch Facility at Lift-Off.
2. **Identify and control every possible source of debris liberation.**

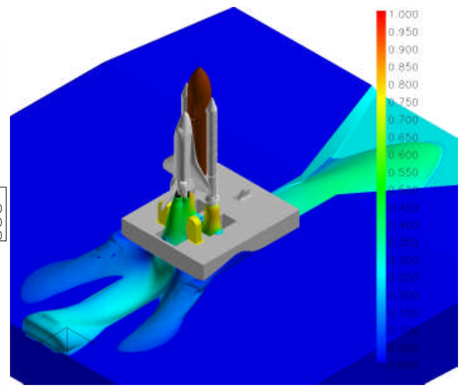
Virtual engineering simulations to validate risk mitigation strategy and to reduce risk to the Vehicle posed by debris.

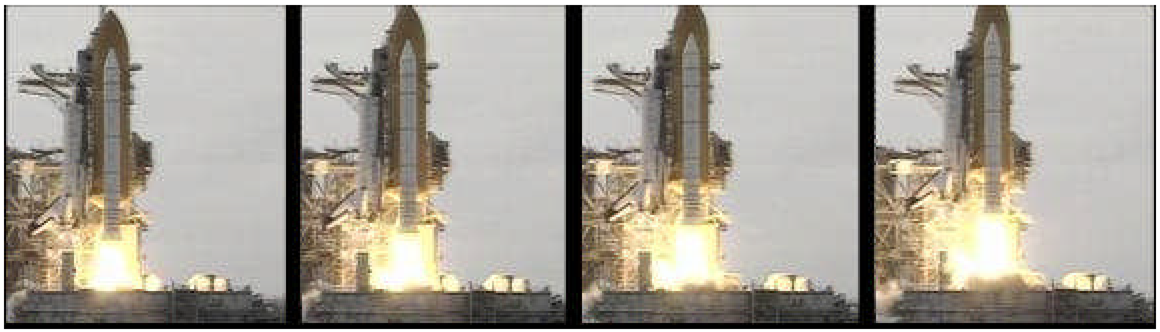
Lift-Off CFD Modeling Approach

Requirements: **Model quasi steady-state time slices simulating Lift-Off sequence – SSME Start, SRBs at Full Thrust, Lift-Off, Throttle-Up, Performance Enhancements Climb-Out, Vehicle Drift**





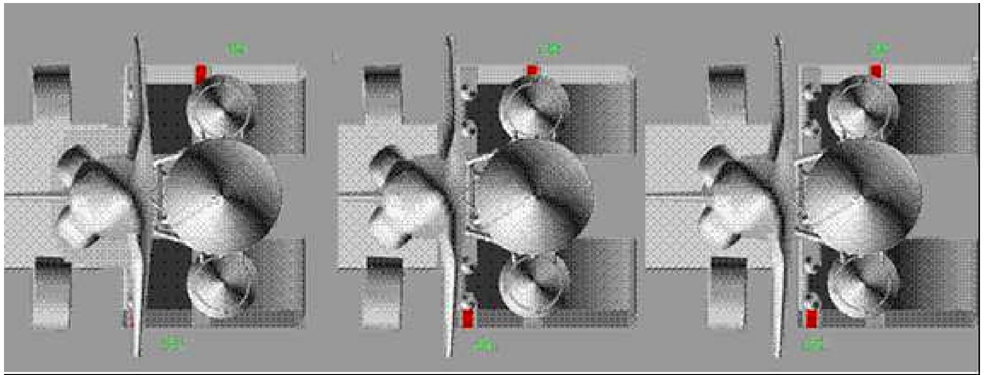




North →

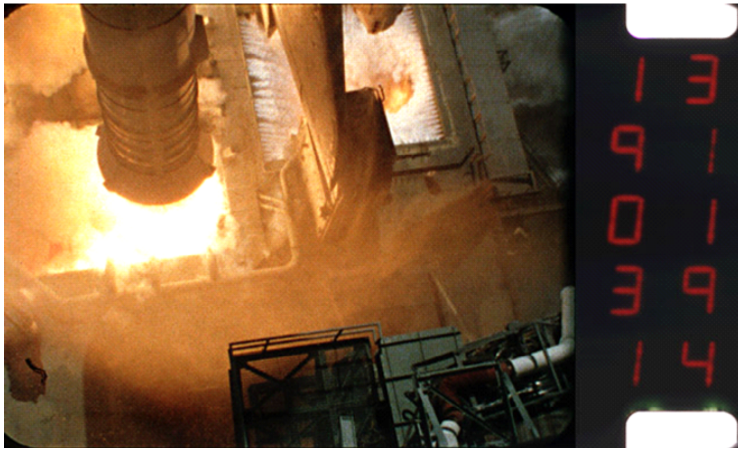
Note: Vehicle drifts North due to the SSME thrust vector

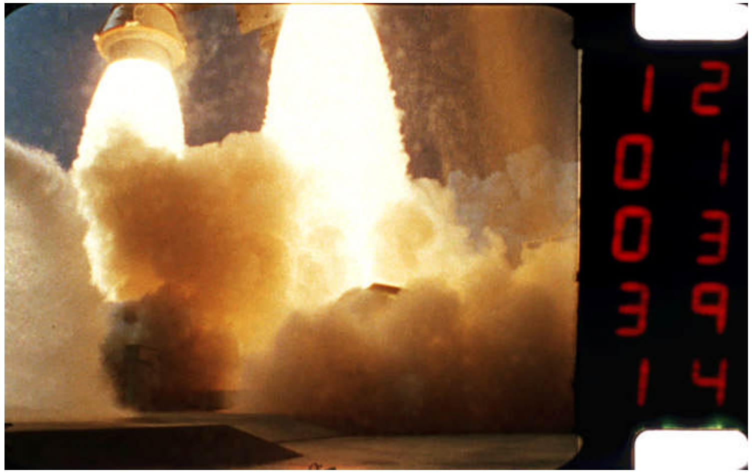
Critical SRB Plume Interactions



North →

a. T0 + 4 sec   b. T0 + 3 sec   c. T0 + 1.9 sec



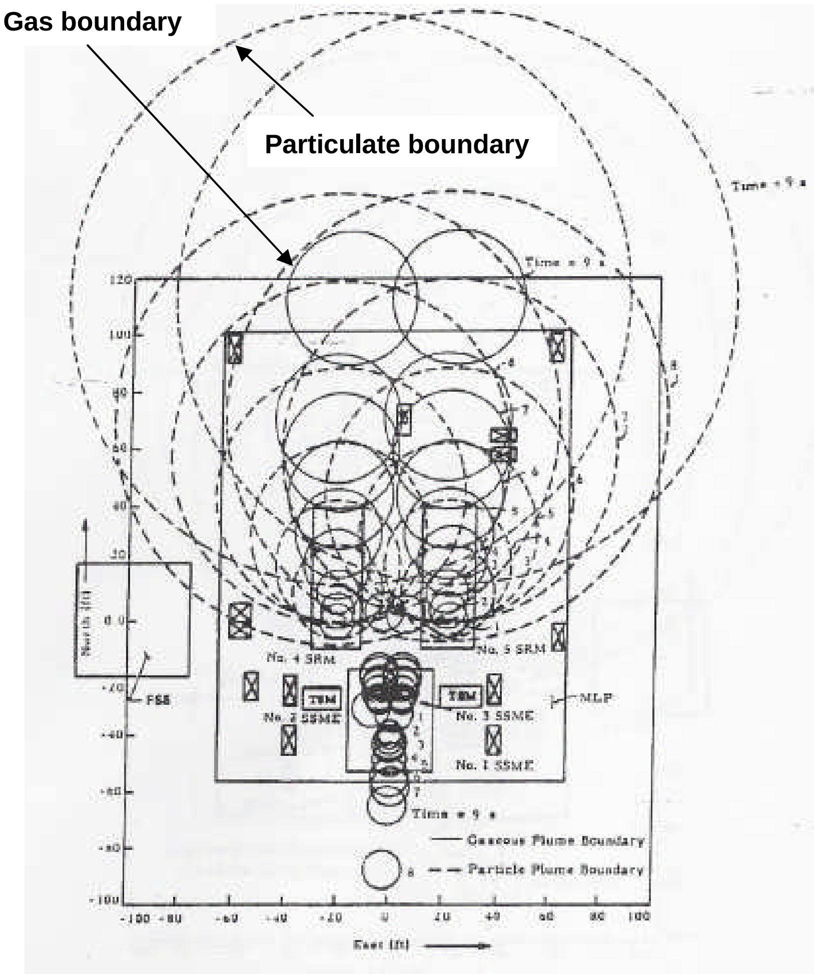


North

a. T0 + 1.9 sec   b. T0 + 3 sec

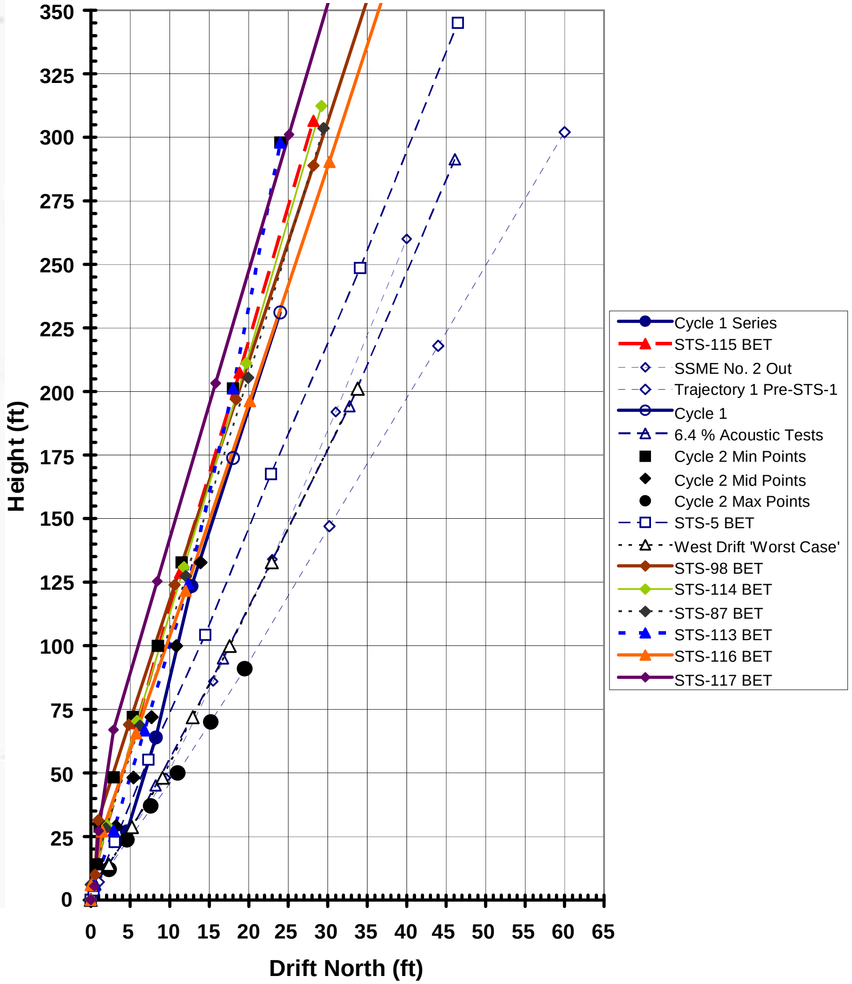
Note: SRB plumes impinge on holddown post/haunches below.

Lift-Off CFD ‘Design of Experiment’



Matrix of Cycle 2 CFD Points North Drift (Nominal)

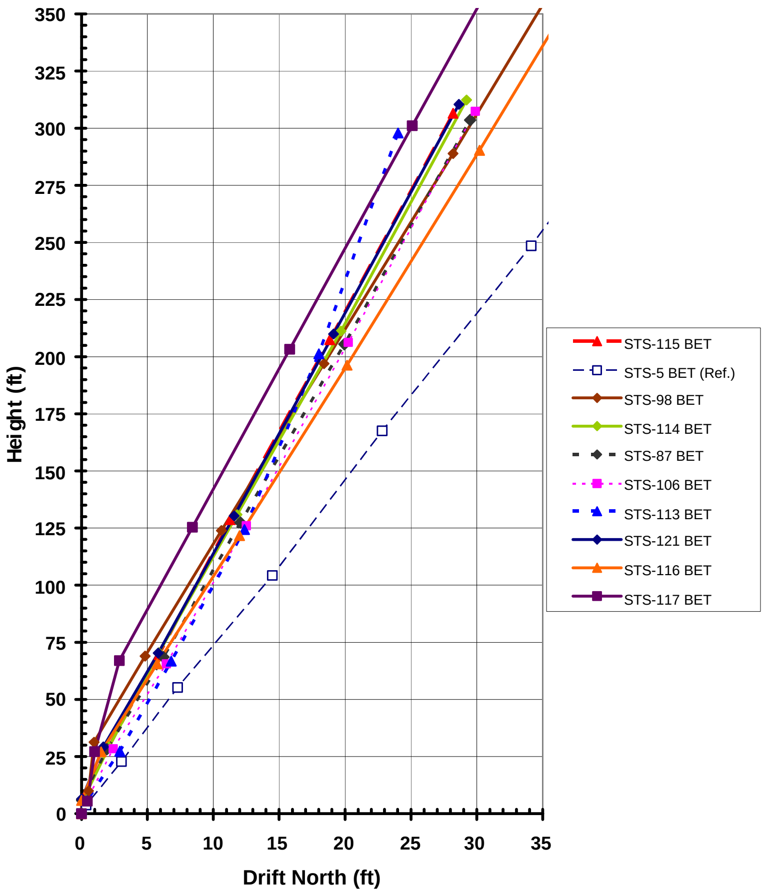
A ‘Min – Mid – Max’ Drift strategy



Note: With the STS-117 flight came a new ‘min’ drift envelope.

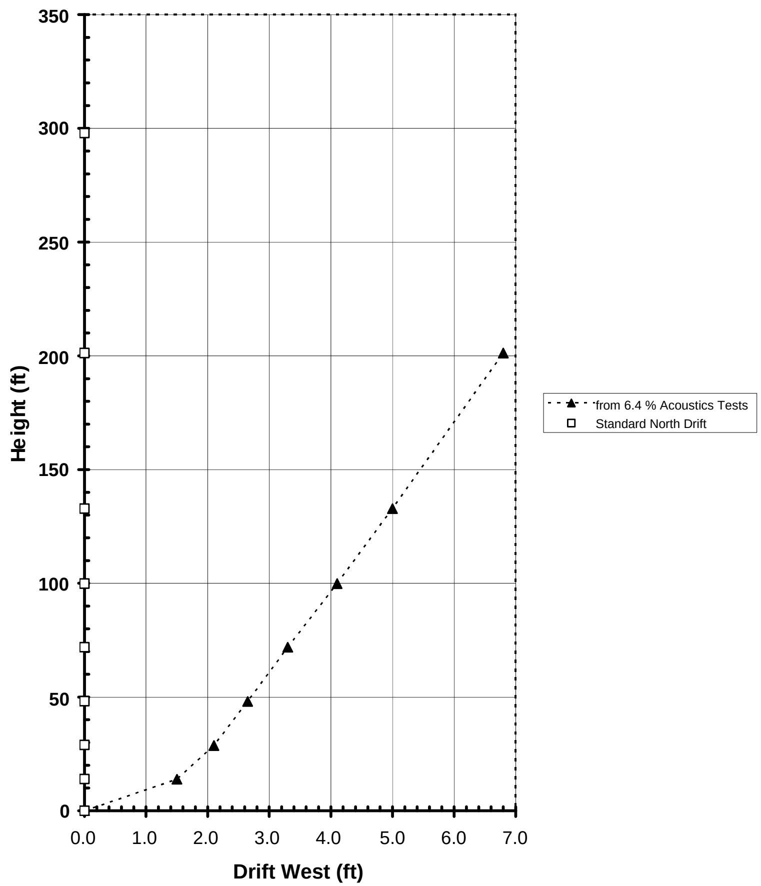
Finding Sensitivities to Drift

Matrix of SSLV Trajectory Points (PE)



Emphasis - Return-to flight since STS-114

Matrix of Cycle 2 Points West Drift 'Worst Case'

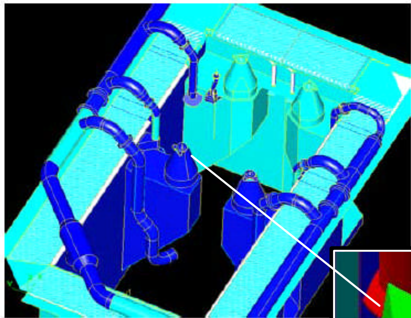


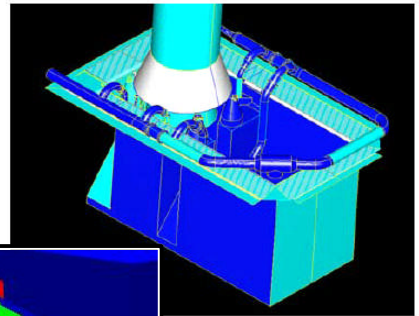
Includes 'worst-case' lateral drift

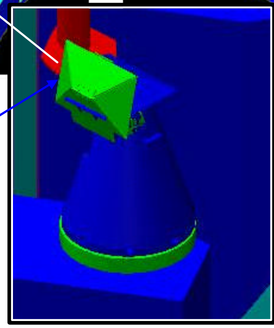
Full 3-D, Single-SRB, ½ - SRB Strategy

Full 3-D Vehicle and Launch Pad Model, up to ~ 100 million grid cells (not shown here, de-featured as necessary to manage total model size)

Use 3-Tiered LO DTA Process: Start screening of debris sources with ½ - SRB Model and all drift matrix points, go to Full SRB Model, and then to Full 3-D Model only as necessary for SRB plume-driven debris.

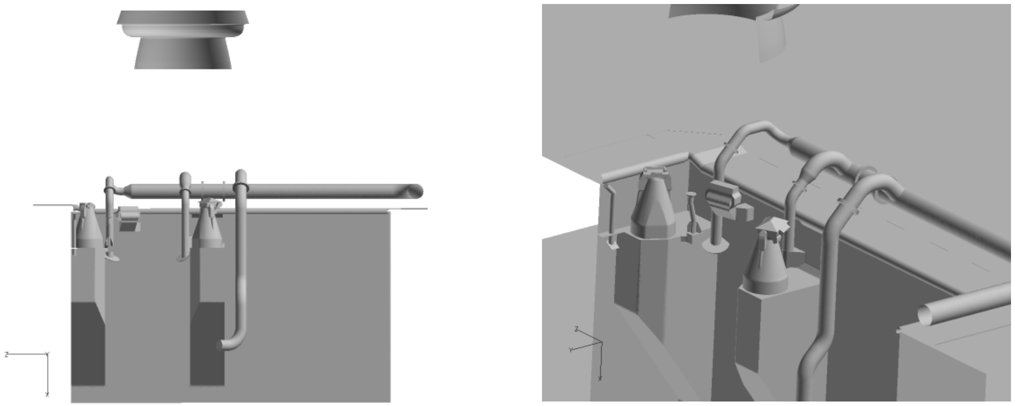






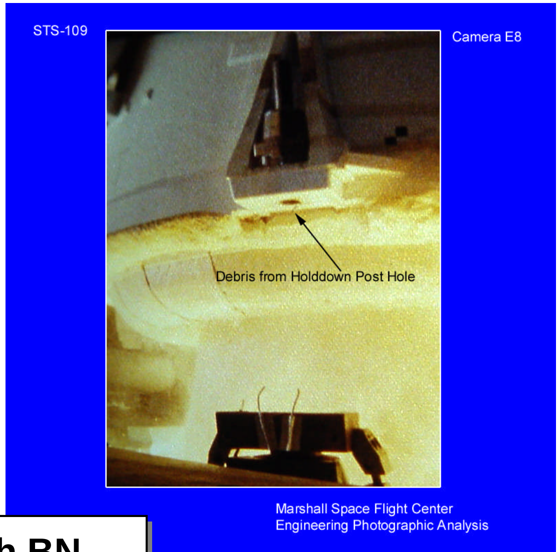
Plume impingement on the North HDP Blast Shields is captured (in closed position).

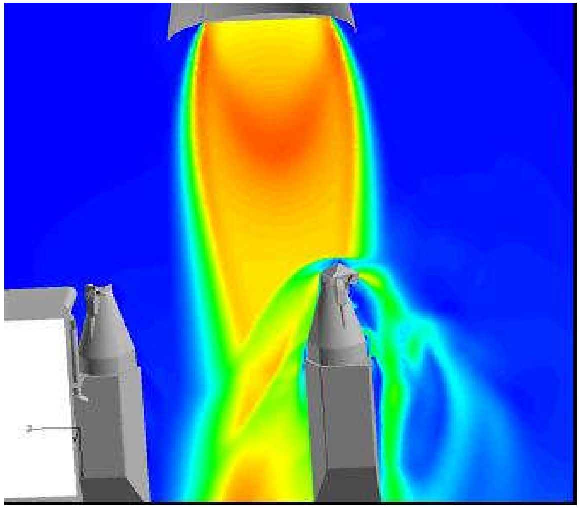
Full SRB Model, up to 120 million grid cells



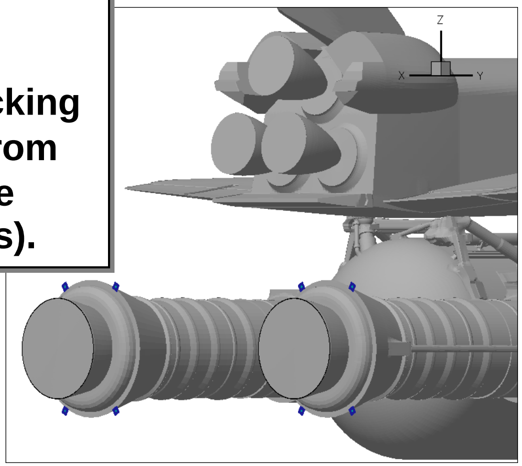
½ - SRB Model, up to 60 million grid cells

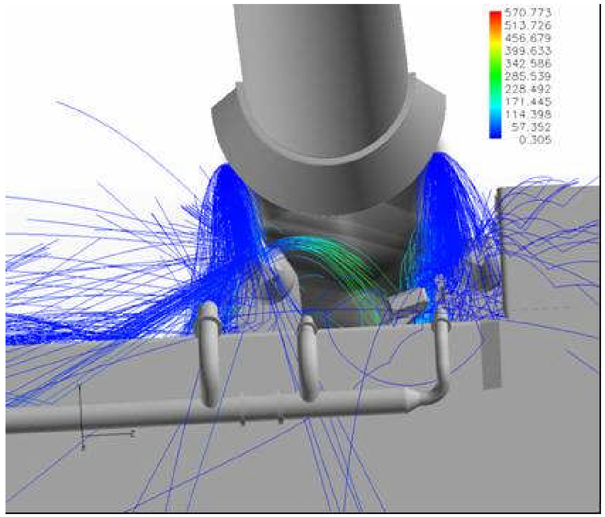
Potential Holddown Nut Shard Debris





Example: a high BN debris particle is released – deterministic tracking where can it go from 8 possible release points (post holes).

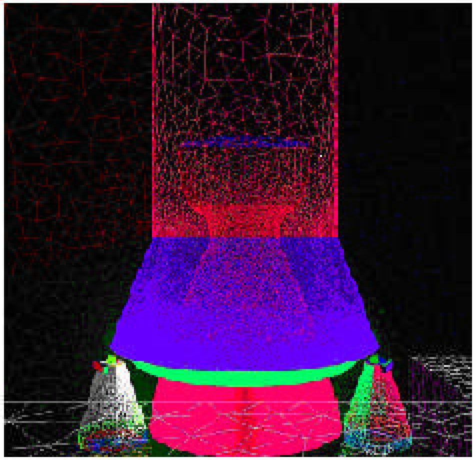


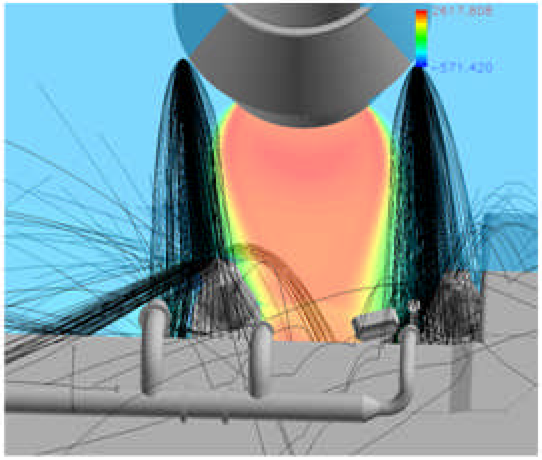


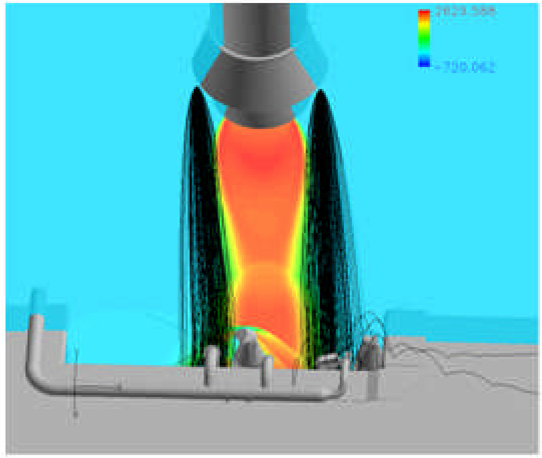
Trajectories colored by particle velocity.

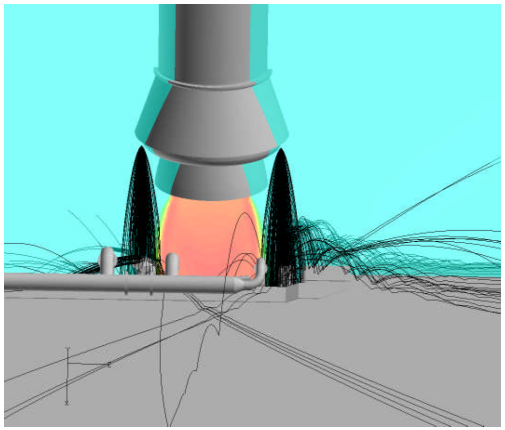
Potential Holddown Nut Shard Debris

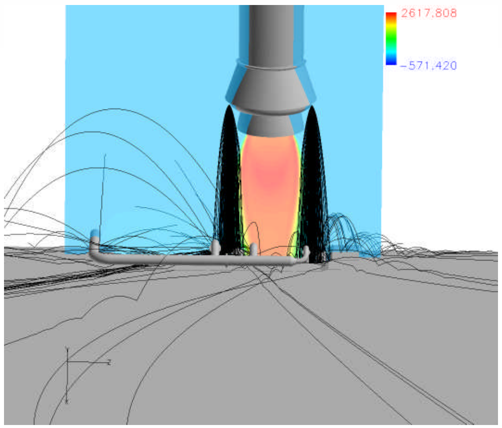
Note: The high BN debris example: six days using 128 cpu's of the Columbia super-computer at NASA/Ames each CFD case shown. Memory usage measured just under 200 gigabytes.











Debris tracing results executed serially under Redhat Linux on an AMD Opteron (tm) Processor 250 with approximately 32 gigabytes RAM, and g95/g++ compilers (thousands of particle trajectories).

Lift-Off Debris Transport Analysis

Concluding Remarks:

1. **The three-tiered analysis approach using Symmetric ½ - SRB, Full SRB, and Full 3-D Integrated Shuttle and Launch Pad CFD models for assessing potential debris has been described.**

2. **Key 'design-of experiment' considerations for potential SRB plume-driven debris analyses have been related:**

    - This for an example SRB plume-driven potential debris case presently in analysis for risk mitigation.

3. **Lift-Off Debris Transport Analysis is in progress to support Shuttle launch and flight operations:**

    - To be based on a series of many potential debris particle trajectory runs.