Space Shuttle Debris Transport

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Debris Sources

Liftoff Debris
rust, uncontained hardware, etc.

Orbital Debris
> 3 km/sec
> 9,800 ft/sec

Ascent Debris
Foam, ice, gap fillers, ceramic inserts, many other smaller and lower likelihood sources.
Probabilistic Debris Process

\[ Pr(\text{failure}) = Pr(E_1 \cap E_2 \cap E_3) = Pr(E_1) Pr(E_2 | E_1) Pr(E_3 | E_1 \cap E_2) \]

- \( E_1 \): Debris Released
- \( E_2 \): Debris Impacts Surface
- \( E_3 \): Impact Exceeds Capability

Void distributions, material properties, heating, etc.

Flowfield, mass, drag coefficient, crossrange, etc.

RCC, tile, windows, ...

\[ f(\text{mass, velocity, angle, material, ...}) \]
Engineering Tools

Modeling & Simulation

Ground/Subscale Test

Flight/Full scale Test
Eliminating Debris Sources

STS-1 thru 4 many modifications
Return To Flight & subs modifications
Multiple ice/frost ramp redesigns
LH₂ flange process changes
Airloads reviews
Aerothermal support

RCS Tyvek® covers
Bipod Ramp Removal
±Z Aero-Vent Modification
LO₂ feedline bracket redesigns
Modified Aft Longeron
STS-121 PAL Ramp Removal
Prelaunch Iceball Assessment Tools
Inflight Damage Assessments

STS-118
Tile Damage

$M_\infty = 18$
$\alpha = 35^\circ$

Insight into local flow properties

Post flight Image
Inflight/Postflight Debris Assessments

Mach 3 Simulation of tile ceramic insert debris

Reaction Control System cover trajectory reconstruction
Computing & Overset Space Shuttle Applications

- Cray X-MP: 0.2 GFLOPS
- Cray Y-MP: 2.5 GFLOPS
- SGI Origin 2000: 128 GFLOPS
- SGI Altix: 2.3 TFLOPS
- SGI ICE / Pleiades: 608 TFLOPS

- ARC3D
- Cray 2: 2 GFLOPS
- Cray C90: 15 GFLOPS
- SGI Origin 3800: 1.2 TFLOPS
- SGI Altix / Columbia: 67 TFLOPS

- F3D
- Chimera Grid Tools
- PEGASUS 5
- OVERFLOW 2.1
- OVERFLOW 2.2

- INS3D
- OVERFLOW 1.6
- OVERFLOW 1.8
- OVERFLOW 2.0

- STS-51L
- STS-107

- NAS Begins

- 1980: $10^5$ grid points
- 1985: $10^6$ grid points
- 1990: $10^7$ grid points
- 1995: $10^8$ grid points
- 2000
- 2005
- 2010

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