Space Shuttle Debris Transport

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Debris Sources

Liftoff Debris
rust, uncontained hardware, etc.

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

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

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

- **E₁**: Debris Released
- **E₂**: Debris Impacts Surface
- **E₃**: 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

Modified Aft Longeron
LO₂ feedline bracket redesigns

STS-121
PAL Ramp Removal
Prelaunch Iceball Assessment Tools
Inflight Damage Assessments

STS-118
Tile Damage

Post flight Image

Insight into local flow properties

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

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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

F3D

Cray C90
15 GFLOPS

Chimera
Grid Tools

OVERFLOW 1.6

OVERFLOW 1.8

OVERFLOW 2.0

OVERFLOW 2.1

OVERFLOW 2.2

PEGASUS 5

INS3D

OVERFLOW 1.6

NAS
Begins

STS-51L

10^5 grid points

10^6 grid points

10^7 grid points

10^8 grid points
