

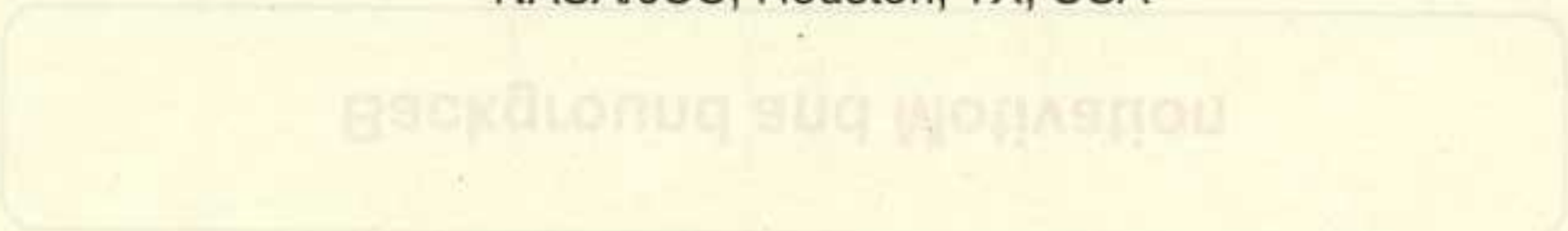
Micro-Satellite Impact Testing

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Background and Motivation

- A key element of modeling the current and future orbital debris environment is the ability to predict the outcome of a typical satellite fragmentation.
- The motivation to conduct new satellite impact tests is
 - to characterize the outcome of future on-orbit fragmentations of satellites with more modern materials, and
 - to cover potential low-velocity collisions in the geosynchronous Earth orbit region.
- The new micro-satellite impact tests aimed
 - to compare low-velocity and hypervelocity impacts on identical target satellites (**completed in 2005**),
 - to investigate the effects of impact directions on fragmentation (**completed in 2007**), and
 - to investigate multi-layer insulation (MLI) and solar panel pieces (**completed last month**).

Target Satellites



- Targets used in 2005 were 15 cm by 15 cm by 15 cm in size and 740 grams in mass (upper).
- Targets used in 2007 were 20 cm by 20 cm by 20 cm in size and 1,300 grams in mass (middle).
- Targets used in 2008, covered with Multi-Layer Insulation (MLI) and equipped with a solar panel, were also 20 cm by 20 cm by 20 cm in size but 1,500 grams in mass (bottom).
- Main structure was composed of five layers (top and bottom and three inner layers) and four side panels, assembled by aluminum alloy angle bars and metal spacers.
- The top and bottom layers and side panels were Carbon Fiber Reinforced Plastics (CFRP) while the inner layers were Glass Fiber Reinforced Plastics (GFRP).
- Each satellite was equipped with fully functional electronic devices.

Impact Scenarios

Shot	M_t [g]	M_p [g]	V_{imp} [km/s]	E_{imp} / M_t [J/g]	Impact Direction [with respect to layers]	Video
HVI	740	4.03	4.44	53.7	normal	N/A
LVI	740	39.2	1.45	55.7	normal	Yes
1	1300	39.2	1.66	41.5	normal	N/A
2	1283	39.2	1.66	42.0	parallel	Yes
3	1285	39.2	1.72	45.1	normal	Yes
F	1525	39.3	1.74	39.0	normal	Yes
R	1515	39.2	1.78	41.0	normal	Yes

M_t = Target Mass, M_p = Projectile Mass

V_{imp} = Impact Velocity, E_{imp} = Impact Energy ($= M_p \times V_{imp}^2 / 2$)

HVI = Hypervelocity Impact, LVI = Low-velocity Impact

Impact Fragmentation (1)



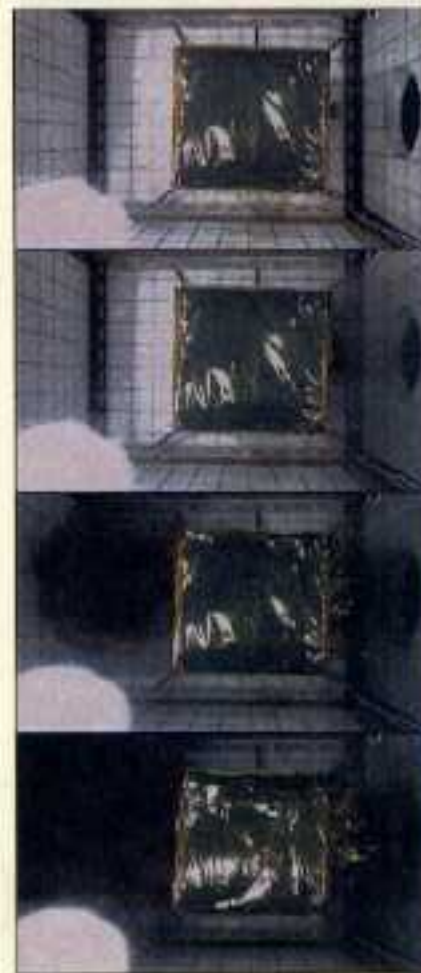
- Shot 3 (\Rightarrow) produced flame, but Shot 2 (\Leftarrow) did not.
- Fragments blew out of the side panels in Shot 3 (\Rightarrow), but not in Shot 2 (\Leftarrow).
- The projectile and fragments created by the impact had to hit the inner layers to create more and more fragments in Shot 3 (\Rightarrow).
- There were no inner layers for the projectile to hit in Shot 2 (\Leftarrow).



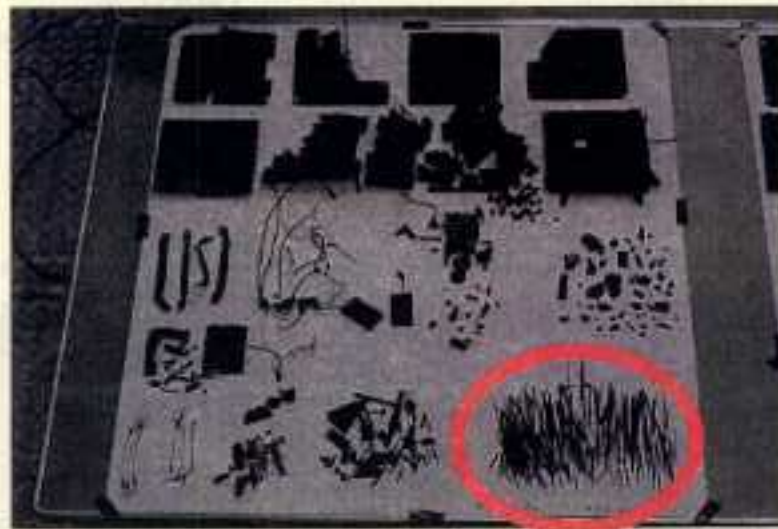
Impact Fragmentation (2)



- The projectile hit first the solar panel in Shot F (\Leftarrow), whereas the projectile hit first the MLI-covered CFRP layer in Shot R (\Rightarrow).
- Shot F (\Leftarrow) produced flame right after the impact, but Shot R (\Rightarrow) did not.
- Shot F (\Leftarrow) generated more fragments than Shot R (\Rightarrow) did.



Fragment Sets From Tests in 2005



	Target mass [g]	Number of fragments collected	Collection rate [%]
HVI (left)	740	1,500	89.9
LVI (right)	740	1,500	94.8

Fragment Sets From Tests in 2007



	Target mass [g]	Number of fragments collected	Collection rate [%]
1 (left)	1,300	1,300	96.2
2 (center)	1,283	1,000	98.3
3 (right)	1,285	1,500	87.9

Fragment Sets From Tests in the Last Month

The collection of fragments is currently in progress.

	Target mass [g]	Number of fragments collected	Collection rate [%]
F (left)	1525	—	—
R (right)	1515	—	—

Summary (1)

- This paper reported seven micro-satellite impact tests, completed through collaboration between Kyushu University and NASA Orbital Debris Program Office.
- The micro-satellite impact tests aimed
 - to compare low-velocity and hypervelocity impacts on identical target satellites (completed in 2005),
 - to investigate the effects of impact directions on fragmentation (completed in 2007), and
 - to investigate multi-layer insulation (MLI) and solar panel pieces (completed last month).
- The kinetic energy at impact in all tests placed the outcome as catastrophic according to the NASA prediction.

Summary (2)

- All target satellites were completely fragmented, consistent with the NASA prediction.
- Fragments collected from the tests in 2005 and 2007 were analyzed based on the method adopted in the NASA standard breakup model.
- The collection of fragments from the last month's tests is currently in progress. Once the collection is complete, fragments will be analyzed based on the method adopted in the NASA standard breakup model.
- The results will be utilized to improve our understanding of the outcome of low-velocity and hypervelocity impacts, and to improve breakup models for better orbital debris environment modeling.