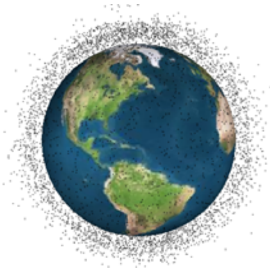
The Orbital Debris Quarterly News



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NEWS

Orbiter Meteoroid/Orbital Debris Impacts: STS-50 (6/92) through STS-86 (10/97), JSC-28033

Post-flight surveys of meteoroid and orbital debris (M/OD) impacts on the Space Shuttle Orbiter are conducted to identify damage caused by hypervelocity impacts from M/OD and to identify the source (i.e., whether meteoroid or orbital debris) of the projectiles responsible. This report provides data on Orbiter M/OD impacts for a five-year period and describes in detail the 20 most significant impacts.

For the period 6/92 through 10/97 there were 40 Shuttle Transportation System (STS) missions (STS-50 through STS-86) of which 29 had post-flight inspections to identify M/OD impacts. Approximately 10% of the vehicle is surveyed in the M/OD inspections.

This work contains estimates of impactor size which were determined using appropriate impact damage penetration equations that were derived by hypervelocity impact (HVI) test and analysis on relevant Orbiter materials. These are summarized in the Appendix. Although predictions for numbers of impacts are produced for each STS mission, those predictions are not compared to the actual damage reported here as further efforts must be made to analyze the as-flown attitude timeline and adjust the predicted damage accordingly.

Current practice calls for documentation of all HVI damage that exceeds the threshold size for Orbiter surfaces included in M/OD surveys as noted in Table 1. If possible within Orbiter processing time tables, JSC M/OD personnel will examine the impact region and obtain a sample of the damage with assistance from KSC.

(Continued on page 3)

Table 1. *Threshold for reporting damage and surface area for Orbiter regions.*

Region inspected	Damage Size Threshold (mm)	Area (m^2)
Windows	0.05	3.4
Radiator Panels	1.0	117
Reinforced Carbon-Carbon (RCC)	0.75	41
Flexible Reusable Surface Insulation (FRSI)	1.0	50

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NEWS, Continued

Orbiter Meteoroid/Orbital Debris Impacts (continued)

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Table 2: Summary of the 20 Most Significant Meteoroid/Orbital Debris Impacts

WINDOWS

Mission #	Duration (days)	Window Location	Flaw Dia. (mm)	Crater Depth (mm)	Particle Type (SEM/EDXA results)	Est. Particle Dia. (mm)
STS-50	13.8	#4, RH forward	7.2	0.57	orbital debris: Ti metal	0.20
STS-59	11.2	#11, side hatch	12.0	0.57	orbital debris: spacecraft paint	0.22
STS-94	15.7	#7, RH overhead	8.2	0.55	orbital debris: metallic Al	0.24

RADIATORS

Mission #	Duration (days)	Radiator Location	Tape Hole Dia. (mm)	Facesheet Hole Dia. (mm)	Particle Type (SEM/EDXA results)	Est. Particle Dia. (mm)
STS-50	13.8	LH #1	3.8	1.1	orbital debris: spacecraft paint	0.5
STS-73	15.9	LH #4	8.3	1.1	orbital debris: spacecraft paint	0.6
STS-79	10.1	RH #3	4.8	1.0	orbital debris: stainless steel	0.1
STS-80	17.7	RH #4	5.5	2.8	orbital debris: stainless steel	1.7
STS-80	17.7	LH #4	3.2	2.0	orbital debris: stainless steel	1.0
STS-81	10.1	RH #4	4.3	1.5	orbital debris: stainless steel	0.3
STS-84	9.2	RH #4	4.0	unknown	orbital debris: stainless steel	0.2
STS-85	11.9	RH #4	5.0	1.3	meteoroid	0.7
STS-86	10.8	ext.manifold-1	0.9 Dia.	0.5 Depth	orbital debris: stainless steel	0.4
STS-86	10.8	ext.manifold-2	1.0 Dia.	0.4 Depth	meteoroid	0.2

OTHER ORBITER COMPONENTS AND PAYLOADS

Mission #	Duration (days)	Impact Location	Damaged Material	Hole Dia. (mm)	Particle Type (SEM/EDXA results)	Est. Particle Dia. (mm)
STS-55	10.0	DEA box of Ku-band antenna	Ag-Teflon Tape on Al	4.1	orbital debris: metallic Al	0.3
STS-56	9.3	reflector of Ku-band antenna	Graphite Epoxy	1.4	meteoroid	0.6
STS-72	8.9	thermal spring seal of rudder speed brake	Inconel, RTV	3.4	orbital debris: metallic Al	1.3
STS-73	15.9	Flexible Reusable Surface Insulation (FRSI) exterior PLB door LH #4	Nomex Felt	17	orbital debris: circuit board components	3 length x 1 dia.
STS-75	15.7	tethered satellite system pallet trunnion	Titanium	1.0	orbital debris: metallic Al	0.8
STS-84	9.2	Flexible Reusable Surface Insulation (FRSI) exterior PLB door RH #2	Nomex Felt	12	orbital debris: metallic Al	2.1
STS-94	15.7	conical seal of vertical stabilizer	Inconel	0.9	meteoroid	0.4

NEWS, Continued

(Continued from page 1)

Post-flight inspection of OV-104 (*Atlantis*) radiator panels after mission STS-86 found a significant M/OD impact in the external manifold hard line that extends along the two forward panels (Figure 1).

The impact penetrated through a beta cloth cover, crossed a 6.4 mm gap, and left a 0.8 mm diameter by 0.47 mm deep crater in the manifold hard line (Figures 2 and 3). The aluminum external hard lines are 0.9 mm thick in the impacted region. From hypervelocity impact data, the crater depth to wall thickness ratio of 0.52 implies that spall effects were likely on the inside of the line at the point of impact. A borescope inspection of the line interior was conducted to assess internal damage and a small area of detached spall was found on the inside of the tube under the impact site. This indicates the impact very nearly put a hole in the external manifold which would have caused a leak of freon coolant, potentially shortening the mission. The Orbiter Project Office has determined that a reasonable approach to reduce the penetration risk in subsequent missions would be to add additional layer of beta cloth to the existing thermal cover on the external manifolds.

Samples obtained for SEM/EDX analysis included the perforated beta cloth thermal cover and tape pull samples from the external line. Analysis found iron (Fe), chromium (Cr), and nickel (Ni) on the beta cloth (teflon-glass background) and in the external line samples, indicating the damage was caused by a stainless steel orbital debris particle.

Post-flight inspection of OV-104 (*Atlantis)* after mission STS-86 showed a second significant M/OD impact in the radiator manifold, located on an external hard line extending from the end of left-hand (LH) panel #3 as indicated in Figure 1. This impact left a 1.0 mm diameter by 0.36 mm deep crater in the radiator manifold which is an aluminum tube 0.9 mm thick. An internal inspection revealed a small bump or attached spall on the interior of the tube directly under the crater. A sketch illustrating the cross-section of the two radiator manifold impacts is given in Figure 4.

Samples from the #2 impact were obtained by wood probe and tape pull and examined by SEM/EDX for residual projectile materials. Based on results of the elemental constituents found, the impact was classified as caused by a meteoroid. ❖

(figures continued on page 4)

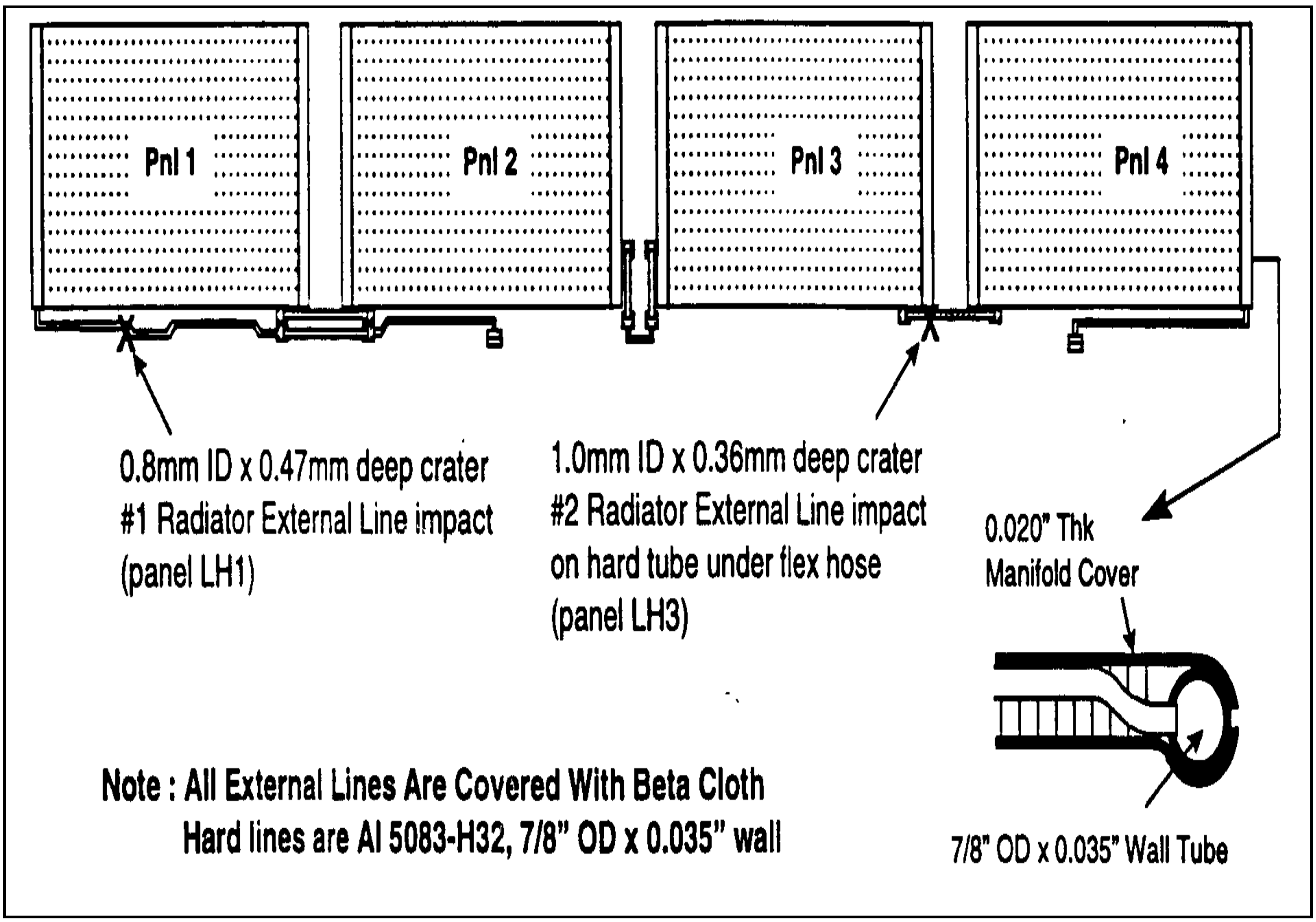

Figure 1. STS-86 location of radiator external line impacts #1 and #2

News, Continued

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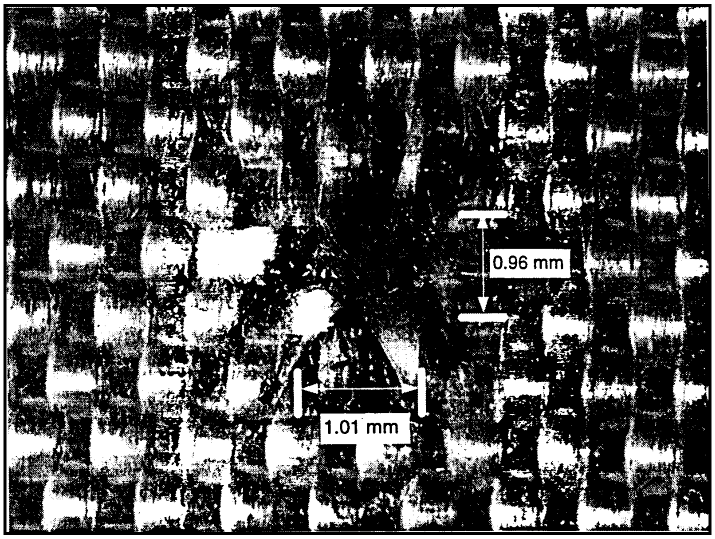

Figure 2. STS-86 1.01 mm x 0.96 mm hole in beta cloth layer in impact #1.

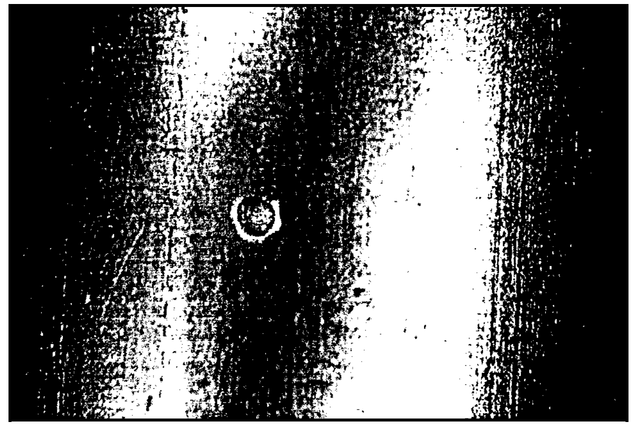

Figure 3. STS-86 crater on aluminum radiator external hard line tube wall (impact #1). Crater depth was over half way through the tube, and damage to the interior surface (detached spall) was found during internal line inspection. Analysis of impact samples indicated the damage was caused by a steel orbital debris particle.

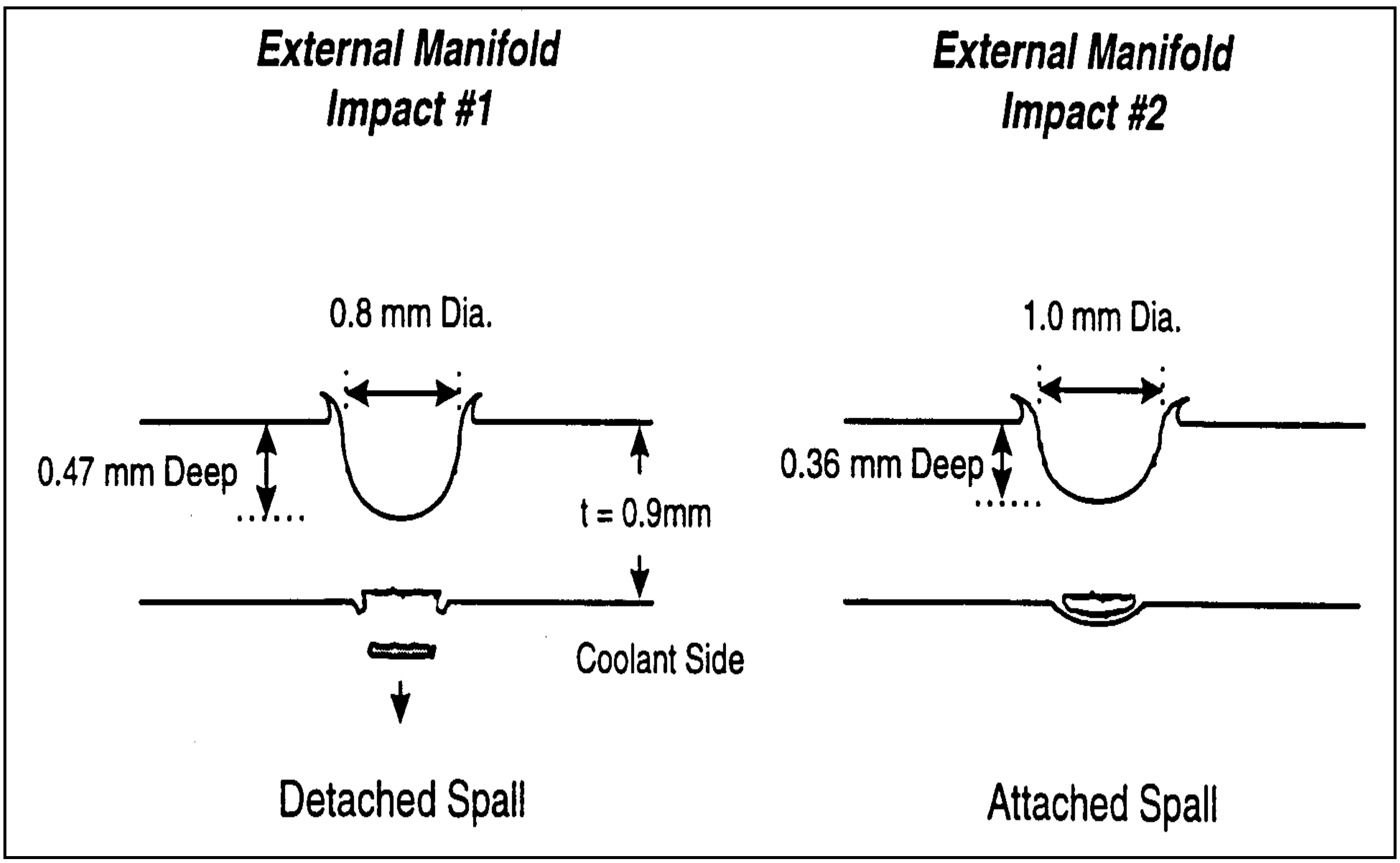

Figure 4. STS-86 crater profiles for external manifold impacts #1 and #2. Orbital debris (stainless steel) caused impact #1, a meteoroid impact caused #2 damage.

News, Continued

LMT Data Work in Progress

Thomas Settecerri and John Africano

The NASA Liquid Mirror Telescope Project has been collecting data on the LEO debris environment since April 1996. From Apr 96 - Apr 97, 47 data tapes were collected using an analog recording system. The tapes have been screened for all moving objects. Preliminary results indicate that 190 uncorrelated targets (UCT) and 61 catalogued objects were detected on the 72 hours of tape. Using these data it is possible to identify debris families based on inclination and altitude. The data complement radar data from Haystack and HAX will be used to look for possible differences in the optical vs. radar populations.

The size limit of detections for the LMT was determined from a correlation factor derived by Dr. Karl Henize which calculates the ratio of total detections to the predicted number of cataloged detections. This ratio, when compared to the size distribution measured by Haystack indicates that the LMT is seeing objects about 3 cm or larger. It is expected with planned new software and hardware upgrades that the minimum size may decrease to about 1.0 cm.

Figure 1 shows the altitude - inclination distribution of the LMT detections below 5000 km. Distinct clustering of detections can be seen in the data similar to what is seen in corresponding plots of radar data.

Figure 2 shows Haystack radar data collected over the same time period. Although both plots have qualitative similarities, a direct comparison cannot be made at this stage in the analysis due to observational biases in both data sets. The LMT can only point straight up from its location and is limited to seeing inclination between 32° - 148°. The collection time at lower altitudes varies due to shadow height and there is no upper range limit to detections. The Haystack plot shows a combination of different viewing angles each having different inclination and altitude limitations. When looking to the south at an elevation of 10°, Haystack is able to detect objects between 28° - 152° inclination at 500 km altitude. Also, both instuments were operated for limited time periods each day introducing other biases which must be accounted for.

The brightness of all objects has also been measured. Figure 3 compares RCS to Absolute Magnitude (brightness corrected for range: range = 1000 km) for the correlated targets. The three lines represent the brightness of spheres having albedos of 1.0, 0.1, and 0.01. It is interesting that the correlated objects are scattered around 0.1 albedo. There may also be some evidence that cataloged intact objects (Figure 3) may have higher albedos than the cataloged debris objects. The UCTs are plotted on the left with their absolute magnitude distribution. The peak of the distribution occurs at 14th magnitude which corresponds to a sphere (albedo = 0.1) of diameter 9 cm. The faintest objects detected correspond to spheres (albedo = 0.1) of diameter 1.5 cm. A RCS may be estimated for each UCT by selecting an albedo on this plot. It appears there are several large UCTs in this data set. ❖

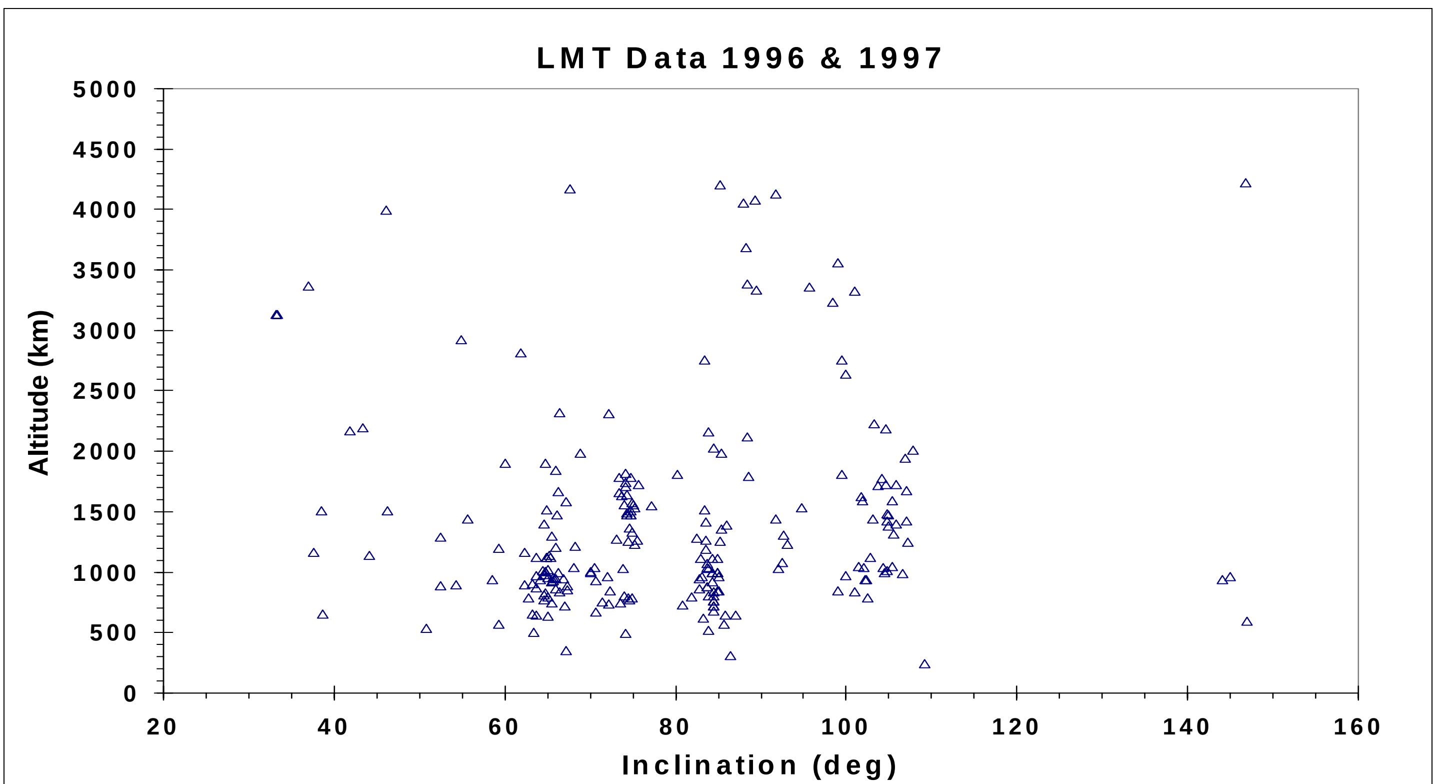

Figure 1. Altitude versus Inclination

News, Continued

LMT Data (continued)

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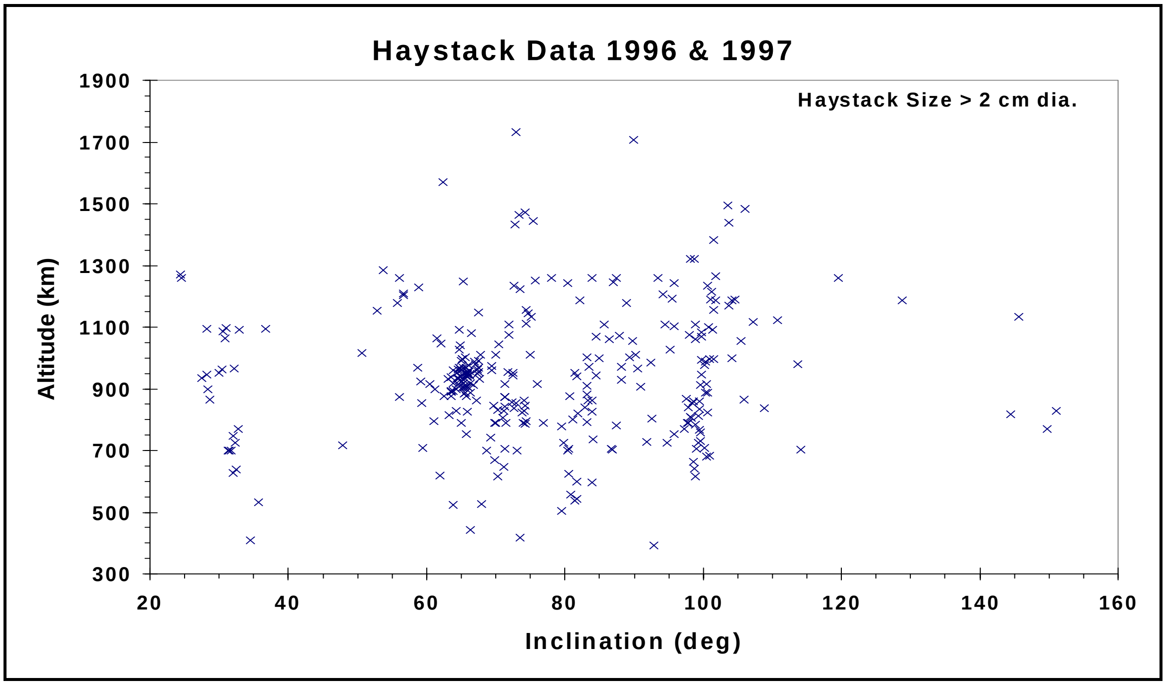


Figure 2. Altitude vs. Inclination

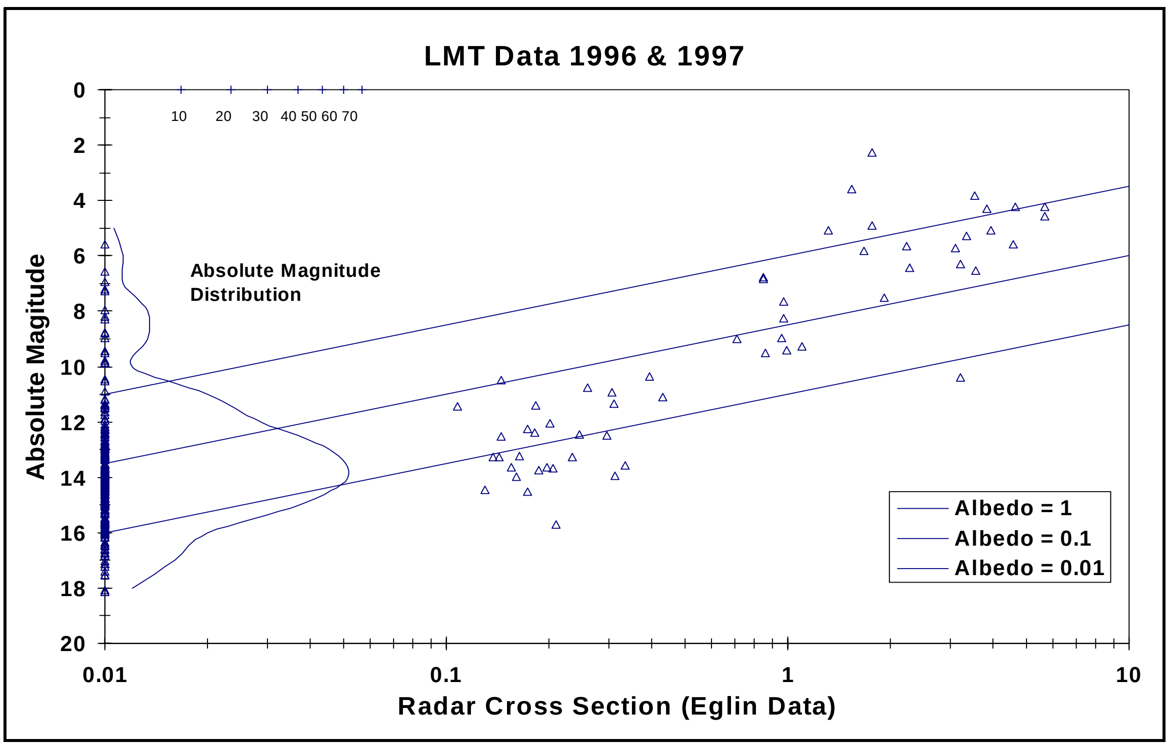


Figure 3. Eglin RCS Data Versus LMT Absolute Magnitude

News, Continued

The Satellite Breakup Risk Assessment Model (SBRAM)

Mark Matney

NASA's orbital debris program has a major objective of characterizing the orbital debris environment. Much of the debris was produced from satellite breakups and other sources many years ago, and there has been sufficient time for the ascending nodes and arguments of perigee of these debris orbits to become thoroughly randomized due to orbital perturbations. This average background flux is modeled in NASA's ORDEM96 program.

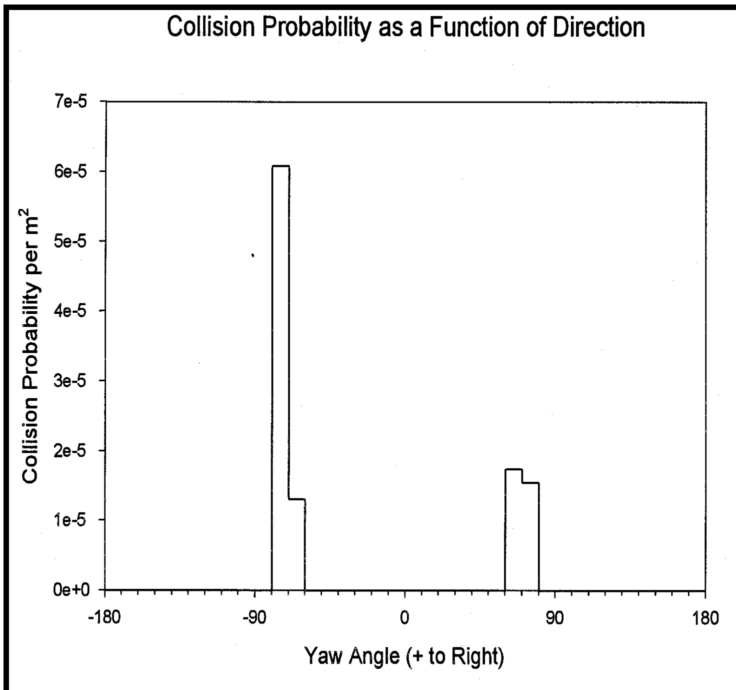
However, the average background flux does not always describe the total risk to a particular space platform. It has long been recognized that enhanced short-term hazards can exist for a period of time after the breakup of a satellite. This hazard can exceed the normal background flux because the cloud of debris produced from the breakup remains concentrated in altitude and orbit plane for a period of weeks or months.

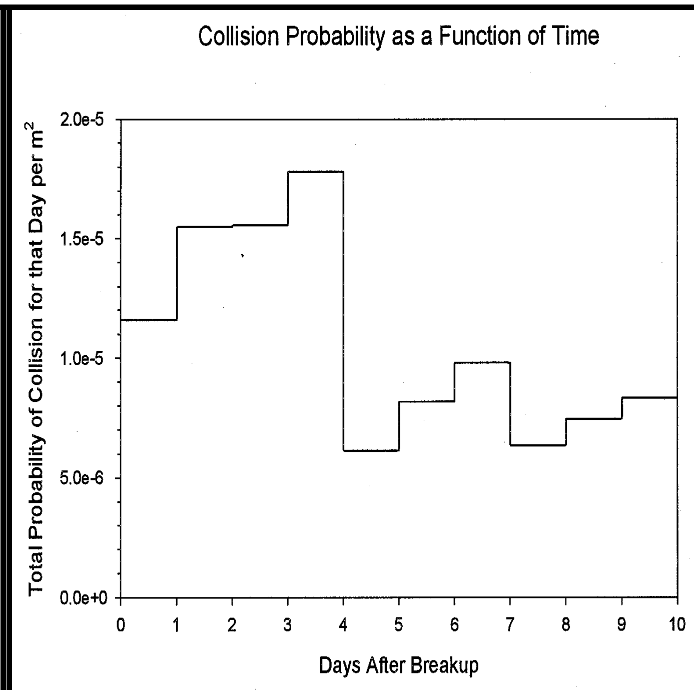
The fact that such short-term risk can pose significant threat to manned space activities has led to the development of the Satellite Breakup Risk Assessment Model (SBRAM). Its primary purpose is to provide a tool with which to make a best assessment of the hazard to an orbital asset (such as the Shuttle, Mir, or International Space Station) in the hours and days that follow an on-orbit breakup event. If necessary, the information can be used to make recommendations on risk-reducing procedures (e.g., rescheduling an EVA).

Previous models have used analytic approaches to study this phenomenon. SBRAM, however, uses a Monte Carlo method to create test clouds of particles and propagate them in time. The initial breakup conditions are set by the actual state vector of the satellite at the time of breakup, and the debris cloud is created using the EVOLVE breakup model. The breakup pieces are assigned ballistic coefficients and initial delta-velocity by the breakup model. The simulated cloud is then randomly dispersed, and the orbits of the debris particles are propagated using the major perturbations and an atmosphere reflecting the current solar activity conditions. This method can be repeated indefinitely until adequate statistics are obtained.

The collision hazard with a spacecraft is computed in a deterministic manner. The target object and the debris objects are propagated to determine potential conjunctions. The actual collision probabilities are arrived at by using three-dimensional probability distributions around the target and debris objects. The overlap of these two distributions for a close encounter determines the collision probability. Each conjunction is saved by the program, and the aggregate data are used to determine overall collision probability statistics.

The figures show a case study of a low-altitude breakup and its risk to the Mir Space Station. The hazard is not uniform over time but varies over a period of days due to the evolution of the debris cloud and the differential precession of the orbit planes of the debris cloud and the target spacecraft. In addition, the direction of the threat from the frame of the target spacecraft can be seen to be narrowly defined in yaw angle over the calculation time. This type of information should prove valuable to risk assessment and planning as Space Station operations commence next year. ❖





News, Continued

Recent Assessment of the Threat Posed by the 1998 Leonid Meteors

Nicholas Johnson

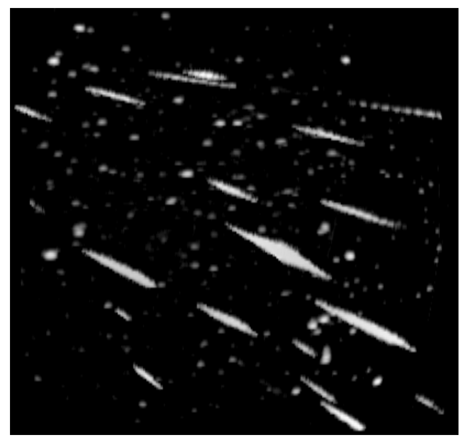
Since 1993 the NASA Orbital Debris Program Office, in conjunction with leading international meteor specialists, has been preparing for the Leonids meteor storm predicted to occur on 17 November 1998. The principal objectives of this activity have been to provide a high-confidence, quantitative assessment of the risks and to assist spacecraft operators with their plans for this short-duration threat. On 4 and 5 June this year, the fruits of the 5-year investigation were briefed to the NASA Administrator and his Senior Management Council, to the Department of Defense, and to the White House's Office of Science and Technology Policy. A synopsis of this work was also shared with the staff of the House of Representatives' Committee on Science.

Although the Leonid meteors are projected to reach storm levels in 1998, the outburst is likely to be substantially lower than that seen in 1966. In fact, based on NASA/JSC analyses led by Dr. Mark Matney of Lockheed-Martin, the flux of Leonid meteors for all size regimes will not exceed the sporadic meteor background. However, the higher velocity (~72 km/s) of the Leonid meteors as compared to the sporadic background means that kinetic energy impact effects and plasma discharge generation will pose greater than normal risks to all spacecraft in near-Earth space, including the L1 region.

The kinetic energy of a Leonid meteor will be 13-18 times that of a sporadic meteor of the same mass. However, since the flux of Leonid meteors is expected to be about an order of magnitude (or more) less than that of sporadics, the flux of the Leonids for a given energy should be of the same order as that of the background. On the other hand, plasma generation effects are approximately proportional to the 4th power of the impact velocity, leading to a significant increase in the threat of this phenomenon. The plasma discharge potential of the Leonids during the 12-hour period centered around the peak activity may be equivalent to as much as a few months of exposure from the sporadics.

A meeting with NASA, NOAA, and DoD spacecraft operators to discuss the threat of the Leonids was held in Houston on 1 July. Measures recommended to reduce spacecraft risks to the Leonids included the minimization of spacecraft cross section (including solar arrays) to the Leonids flux, the reorientation of sensitive spacecraft surfaces away from the Leonids radiant, the powering-down of non-critical systems, the development of software to counter the likely effects of plasma discharge, and the augmentation of crews at spacecraft operations centers.

Simple software developed by Bill Cooke of Marshall Space Flight Center to calculate possible Leonid meteor fluence for spacecraft in Earth orbit can be found on the world-wide web at http://see.msfc.nasa.gov. NASA/JSC will establish a network to collect, and, as appropriate, to exchange reports of spacecraft anomalies during the Leonids storm. For further information please contact Dr. Walter Marker at 281-483-0117 or walter.marker1@jsc.nasa.gov. ❖



Project Reviews

Meteor 2-16 RB Debris Observations: Tsyklon Breakup

Thomas Settecerri

On February 15, 1998, a Ukranian Meteor 2-16 Rocket Body (Tsyklon third stage) broke up in orbit at an inclination of 82.6° at approximately 950 km altitude. The U.S. SSN detected 115 pieces greater than 10 cm in diameter. On February 26, the Haystack radar was tasked to track the orbit plane of this breakup to find additional objects. Figure 1 was generated to isolate detected objects within 5° of Satellite 18313's original inclination. Figure 2 shows the Haystack data most likely associated with the breakup and data from USSPACECOM. Further analysis of these two data sets will yield a breakup distribution. Figure 3 shows the apogee and perigee for the satellite, the USSPACECOM catalog objects, and the mean altitude of the Haystack detections associated with this breakup. ❖

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Project Reviews, Continued

Meteor 2-16 RB Debris Observations: Tsyklon Breakup (continued)

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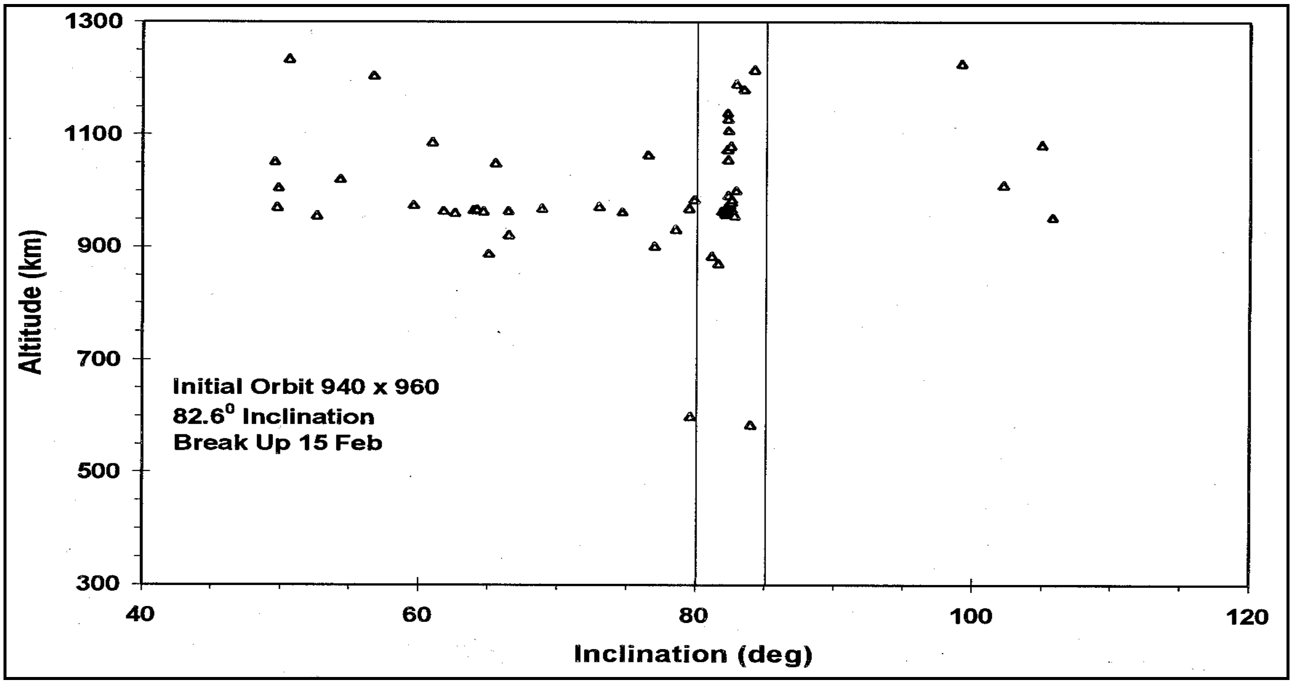

Figure 1. Haystack Data February 26, 1998

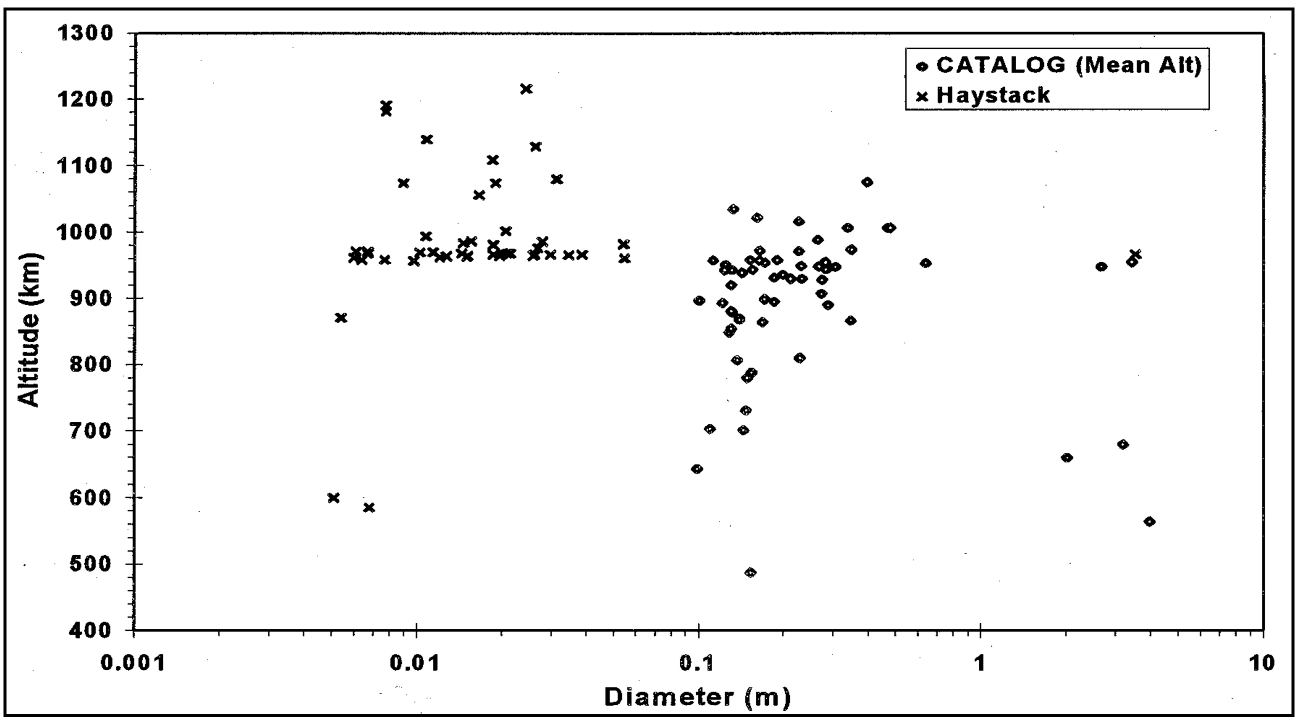

Figure 2. Haystack and USSPACECOM, May 20, 1998

Project Reviews, Continued

Meteor 2-16 RB Debris Observations: Tsyklon Breakup (continued)

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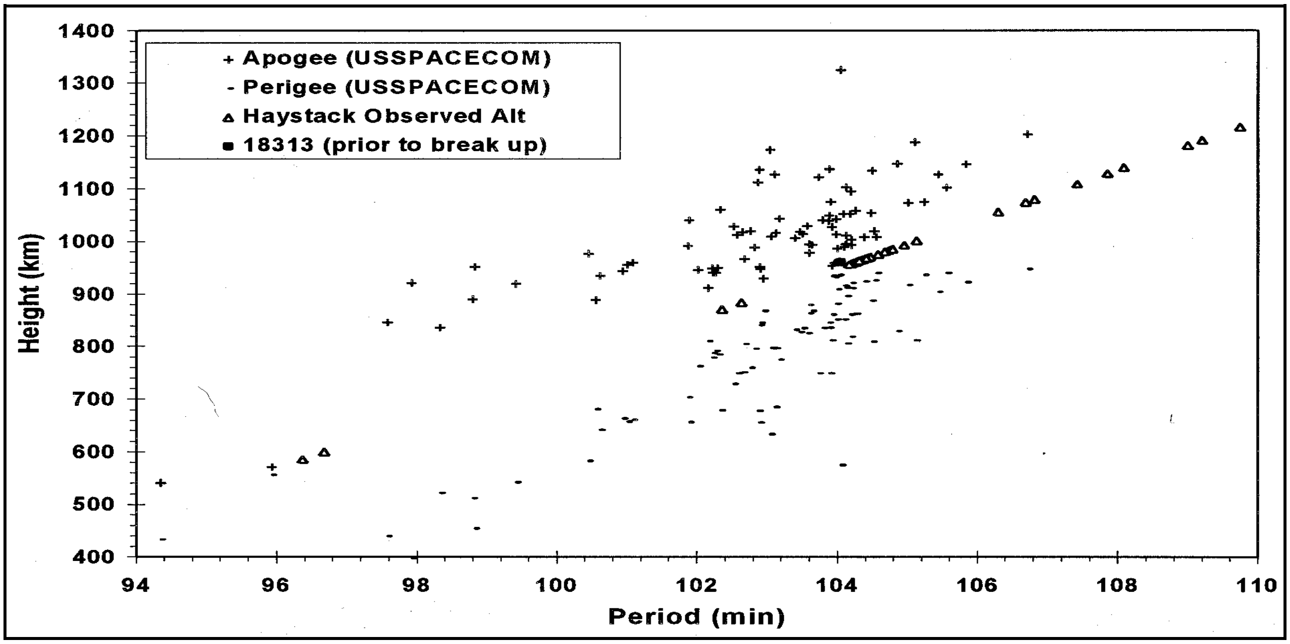


Figure 3. Gabbard Diagram of Breakup 18313

Capture of Hypervelocity Particles with Low-Density Aerogel, NASA TM-98-201792

Low-density (0.01-0.05 gm/cm^3) SiO_2 aerogel affords new opportunities to decelerate high-speed particles without substantial melting. NASA's Orbital Debris Collector exposed samples of Aerogel on the exterior of the Mir Space Station during the period March 1996 to October 1997, and a similar collector is envisioned for the Stardust spacecraft which will rendezvous with comet Wild 2. This April 1998, 60-page report by a team of scientists from NASA Johnson Space Center, the Jet Propulsion Laboratory, Lockheed-Martin Space Mission Systems and Services, and the University of Washington, summarizes attempts to evaluate the performance of low-density aerogels in the capture of hypervelocity particles.

The principal test projectiles were between 43 and 54 microns in diameter with impact velocities of 3-7 km/s. The experiments showed that the definition of the initial impact conditions for such small projectiles poses a substantial challenge when using light-gas guns and associated shot-gunning methods for particle acceleration. An inability to precisely machine the test microspheres to specified diameters and shapes without microcracks or other flaws hinders experiment reproducibility and leads to large data scatter. In addition, consistency of exact aerogel density appears difficult to accomplish, leading to variations in target density which may be a contributing factor in producing large variances from experiment to experiment.

Consequently, no reliable experimental basis to utilize penetration tracks in aerogels currently exists for the reconstruction of the initial mass or encounter velocity of man-made orbital debris or natural cosmic dust particles. Improved control of the initial size, mass, and shape of the projectiles as well as aerogel density is needed to yield more reproducible experiments and a more reliable basis to understand deceleration of very small hypervelocity impactors by targets of very low density and exceptionally high porosity.

Nevertheless, the present study shows that the density of aerogel greatly affects the length of the resulting penetration track. At both high incident and oblique angles, the resulting penetration tracks faithfully recorded the angle of incidence relative to the collector surface, yet the absolute track length was unaffected by impact angle. These observations lend strong support for a model which suggests that most deceleration of hypervelocity particles in highly porous, low density targets is governed by viscous drag rather than by classical shock and cratering processes. ❖

Abstracts From Papers

The Cause and Consequences of a Satellite Fragmentation: A Case Study

Nicholas Johnson

The fragmentation of a Pegasus Hydrazine Auxiliary Propulsion System upper stage on 3 June 1996 stands as the worst satellite breakup on record in terms of cataloged orbital debris. In addition to the more than 700 debris large enough to be tracked (approximately 10 cm in diameter or greater) in the 200 km by 2,000 km orbital regime by the U.S. Space Surveillance Network, a debris population of up to 300,000 objects larger than 4 mm appears to have been generated, based upon special radar observations. The debris cloud presented an immediate threat to many resident space objects, such as the Hubble Space Telescope, which resided in an orbit just 25 km below the breakup altitude. Special analyses were required to ensure the safety of the STS-82 Hubble Space Telescope servicing mission in February 1997. This paper describes the activities undertaken at the National Aeronautics and Space Administration Lyndon B. Johnson Space Center to characterize the near-term and far-term hazard of the debris cloud to manned and robotic spacecraft and to investigate the probable cause of the accident. The role of composite materials in the vehicle may have led to the creation of a much larger number of debris than would have been expected from a more conventional upper stage. To avoid a repetition of the incident, the Hydrazine Auxiliary Propulsion System upper stage was modified before its next launch, and additional passivation measures were adopted. This fragmentation event represents a textbook case for the hazards posed by satellite breakups and how fragmentation potential can be reduced without significantly affecting the capability of the vehicle. ❖

Sensitivity Analysis of the Orbital Debris Environment Using EVOLVE 4.0

Robert Reynolds, Peter Eichler, Anette Bade, Paula Krisko and Nicholas Johnson

A number of models to describe the current and future orbital debris environments have been developed at NASA/JSC. One of these models, EVOLVE, is a complex simulation model that uses future space traffic, fragmentations, and non-fragmentation processes to predict future environments for debris 1 mm in diameter and larger. New breakup models incorporating new data on orbiting fragmentation debris, as well as new data from laboratory tests, are being developed for use by EVOLVE. These models will have different size, area-to-mass, and velocity distributions than in the current baselines. With the inclusion of the new breakup models, EVOLVE will be upgraded to version 4.0.

Because there is limited data on debris sources and uncertainty in the importance of these sources in future debris environment evolution, it is important to understand the sensitivity of environment projections to these uncertainties. To calculate the sensitivity of the environment to characteristics of the debris sources, alternative environment projections will be obtained by making a series of modifications to the nominal source characteristics in EVOLVE. Metrics for measuring change in the environment will be defined in this paper and used to discuss sensitivities. ❖

Recent Results From Goldstone Orbital Debris Radar

Mark Matney, Richard Goldstein, Donald Kessler and Eugene Stansbery

On a limited basis, the National Aeronautics and Space Administration's (NASA's) Goldstone X-band radar has been available to monitor the orbital debris environment. This powerful radar, which can detect a 3 mm diameter conducting sphere at a range of 1,000 km, fills a niche in NASA's ongoing program to monitor and mitigate the hazard of orbital debris.

In this paper, we present flux measurements and other results of several years of monitoring. Some of the debris objects are observed to orbit in clusters, which indicates a common origin for them. One such cluster appears to be the remnants of 350 million copper dipoles, launched in 1961 as a communications experiment. ❖

The Importance of Nonfragmentation Sources of Debris to The Environment

Donald Kessler, Nicholas Johnson, Eugene Stansbery, Robert Reynolds, Karl Siebold, Mark Matney and Albert Jackson

Historically, satellite fragmentation has been assumed to be the major source of small orbital debris, based on U.S. Space Command observations. Although it was always known that only a few tens of kilograms of small debris could produce a significant debris hazard, there was no hard evidence that any space operations were releasing even these small quantities. Recent observations of small debris have led to the discovery of numerous nonfragmentation sources; in some cases, these sources have produced a hazard that exceeds the hazard from satellite breakups. In the centimeter-size range, these findings include aluminum oxide slag from solid rocket motors, sodium potassium droplets from coolant systems, and copper needles from U.S. experiments. Smaller debris include paint flecks from spacecraft surfaces and aluminum oxide dust from solid rocket motors. Since the number of known debris sources seems to be proportional to the amount of effort expended looking for new sources and since observation programs to measure the small debris environment have just begun, many more sources are likely to be identified. These nonfragmentation sources could increase the need for mitigation efforts and complicate cost/benefit analyses of current efforts. ❖

Haystack Measure of the Orbital Debris Environment

Thomas Settecerri, Eugene Stansbery and Mark Matney

The Haystack radar has been observing the orbital debris environment since October 1990. These measurements have provided orbital debris researchers with two important tools for characterizing the environment: 1) the ability to detect small size debris objects from previously unknown sources and 2) the ability to extend the size distribution from the catalog limit (~10 cm) down to 0.5 cm. Haystack data has identified small debris from several breakups and anomalous events: the Pegasus upper stage, satellite 23106; Cosmos 1484, satellite 14207; COBE, satellite 20332; Meteor 2-16 rocket body, satellite 18313; and the leakage of NaK droplets from the RORSAT class satellites. The time history of detection rate and the flux, altitude, inclination, and size distributions have shown that the environment is very dynamic and the data is extremely useful as a benchmark for orbital debris modeling. ❖

Presented at
The 32nd COSPAR Scientific Assembly Nagoya, Japan
July 12-19, 1998

INTERNATIONAL SPACE MISSIONS
April - June 1998

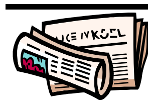
International Designator	Payloads	Country/ Organization	Perigee (KM)	Apogee (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
1998-020A	TRACE	USA	644	597	97.8	1	0
1998-021A	IRIDIUM 62	USA	780	775	86.4	0	0
1998-021B	IRIDIUM 63	USA	780	775	86.4		
1998-021C	IRIDIUM 64	USA	780	776	86.4		
1998-021D	IRIDIUM 65	USA	780	776	86.4		
1998-021E	IRIDIUM 66	USA	783	772	86.4		
1998-021F	IRIDIUM 67	USA	780	774	86.4		
1998-021G	IRIDIUM 68	USA	781	774	86.4		
1998-022A	STS 90	USA	286	257	39.0	0	0
1998-023A	GLOBALSTAR 5	USA	1428	1399	52.0	1	0
1998-023B	GLOBALSTAR 6	USA	1425	1402	52.0		
1998-023C	GLOBALSTAR 7	USA	1429	1398	52.0		
1998-023D	GLOBALSTAR 8	USA	1424	1403	52.0		
1998-024A	NILESAT	ESA	35795	35778	0.0	1	1
1998-024B	B-SAT 1B	Japan	35829	35815	0.1		
1998-025A	COSMOS 2350	Russia	35817	35756	2.2	2	1
1998-026A	IRIDIUM 69	USA	780	775	86.4	2	4
1998-026B	IRIDIUM 71	USA	781	775	86.4		
1998-027A	COSMOS 2351	Russia	39200	509	63.0	2	3
1998-028A	ECHOSTAR 4	USA	35792	35781	0.0	2	1
1998-029A	USA 139	USA	No Elements Available			1	0
1998-030A	NOAA-K	USA	819	807	98.7	0	0
1998-031A	PROGRESS M-39	Russia	298	254	51.7	1	0
1998-032A	IRIDIUM 70	USA	778	777	86.4	1	1
1998-032B	IRIDIUM 72	USA	780	776	86.4		
1998-032C	IRIDIUM 73	USA	780	776	86.4		
1998-032D	IRIDIUM 74	USA	779	777	86.4		
1998-032E	IRIDIUM 75	USA	Enroute to Operational Orbit				
1998-033A	CHINASTAR 1	PRC	37661	33914	0.1	1	0
1998-034A	STS 91	USA	373	350	51.7	0	0
1998-035A	THOR 3	Norway	35819	35754	0.1	2	0
1998-036A	COSMOS 2352	Russia	1875	1310	82.6	1	0
1998-036B	COSMOS 2353	Russia	1870	1300	82.6		
1998-036C	COSMOS 2354	Russia	1872	1307	82.6		
1998-036D	COSMOS 2355	Russia	1868	1302	82.6		
1998-036E	COSMOS 2356	Russia	1868	1298	82.6		
1998-036F	COSMOS 2357	Russia	1864	1293	82.6		
1998-037A	INTELSAT 805	Intelsat	35802	35771	0.1	1	0
1998-038A	COSMOS 2358	Russia	334	167	67.1	1	1
1998-039A	COSMOS 2359	Russia	290	170	64.9	1	0

Upcoming Meetings

The ***Hypervelocity Impact Symposium,*** Von Braun Center in Huntsville, Alabama, November 16-20, 1998. Web site: http://www.futureonline.com/hvis/main.html.

The ***49th International Astronautical Congress (IAF),*** Melbourne, Australia, September 28-October 2, 1998. Web site: http://www.iafastro.com.

The ***16th Inter-agency Space Debris Coordination Committee (IADC)*** meeting, Toulouse, France; November 3-6, 1998.



Next Issue

- **Telescope observations of Orbital Debris**
- **Breakup Model Update Part II: Delta Velocity Determination**

ORBITAL BOX SCORE

(as of 30 June 1998, as catalogued by US SPACE COMMAND)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	23	101	124
CIS	1336	2579	3915
ESA	23	206	229
INDIA	17	4	21
JAPAN	63	53	116
US	708	3182	3890
OTHER	329	25	354
TOTAL	2499	6150	8649

Editor's Note

Robert Reynolds

One of the major issues in orbital debris modeling has been the shortage of data on the debris environment smaller than 10 cm and the particularly limited data on those debris smaller than 1 mm. In this issue of the newsletter we feature several articles that provide an update of ongoing efforts at JSC to provide those types of data.

The manned space program, both with the STS and Mir, provides multiple opportunities to examine surfaces returned from space. The information contained in impacts on these surfaces is often difficult to interpret because of the contaminated environment surrounding the orbiting systems and because of the lack of complete flight attitude data, but these surfaces do represent the potential best source of such data for LEO. The recently released report by Eric Christiansen and his co-workers (JSC 28033) summarizes studies of the Orbiter from flights starting in 1992. These data helped in developing the current NASA engineering model ORDEM96 and should be of great interest to the entire orbital debris community.

Looking to the future, development of small particle capture cells using low density aerogel will facilitate acquiring improved data for missions where the cells can be returned for analysis. The status for using this medium is the subject of the recently released NASA report NASA-TM-98-201792.

Finally we have new results from the debris observations with the liquid metal mirror telescope (LMT). John Africano has recently joined the research group here in Houston and will be working on optical data exclusively. We welcome John into the group and look forward to seeing the LMT contributing to our effort to better understand debris sources and small particle environmental conditions. ❖

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