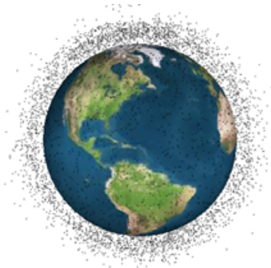
The Orbital Debris Quarterly News



A publication of

The Orbital Debris Program Office
NASA Johnson Space Center
Houston, Texas 77058

October 1998 **Volume 3, Issue 4**

NEWS

Imagery Survey of the Hubble Space Telescope

During the second servicing mission of the Hubble Space Telescope (HST) by the STS-82 mission in February 1997, an extensive imagery survey was performed covering approximately 97% of the HST surface. The results of a dedicated study to identify and to characterize apparent micrometeoeroid and orbital debris (M/OD) impacts have been recently documented in a new NASA JSC report, "Survey of the Hubble Space Telescope Micrometeoroid and Orbital Debris Impacts from Service Mission 2 Imagery," by G. J. Byrne, D. R. Bretz, M. H. Holly, M. T. Gaunce, and C.A. Sapp.

Employing video, photography, and electronic still imagery (a total of 2500 still frames and 17 hours of video), the analysis team was able to identify 788 potential impacts on the HST aft shroud, equipment section, aft bulkhead, grapple fixtures, aperture door, and solar arrays. The analysis process involved first screening and categorizing the images, then imagery review and M/OD impact identification, followed by mapping and measurements of the impact features.

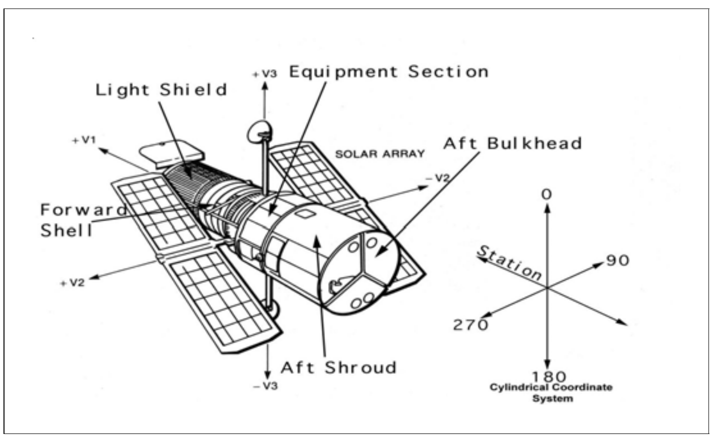


Figure 1. Hubble Space Telescope, Major Components, and Coordinate Systems

Over 500 of the impacts were found on the aft shroud and equipment section where highly reflective surfaces facilitated detection of impact features. Approximately 80% of the impact zones measured less than 0.8 cm, although the largest was 4.7 cm in diameter.

A plot of the number of impacts of a given outer diameter size range illustrates the expected exponential increase down to a size of 0.4-0.5 cm, where sensitivity limits of the imagery apparently lead to a reduced count. The distribution of impacts around the aft shroud suggest a real difference in the number of particle impacts on the +V3 and the –V3 sides.

An attempt was also made to compare the number of impacts seen on the first servicing mission in December 1993 (after 44 months exposure in LEO) and the second servicing mission (after an additional 38 months exposure in LEO). A limited comparison of the +V3 quadrant showed an increase in the density of observed strikes from approximately 5 impacts per square meter to approximately 20 impacts per square meter. While some of this increase is undoubtedly due to the superior quality of the imagery obtained during the second servicing mission, a change in the environment may also be indicated.

The next servicing mission to HST is scheduled for May 2000, and an additional imagery survey is planned. ❖

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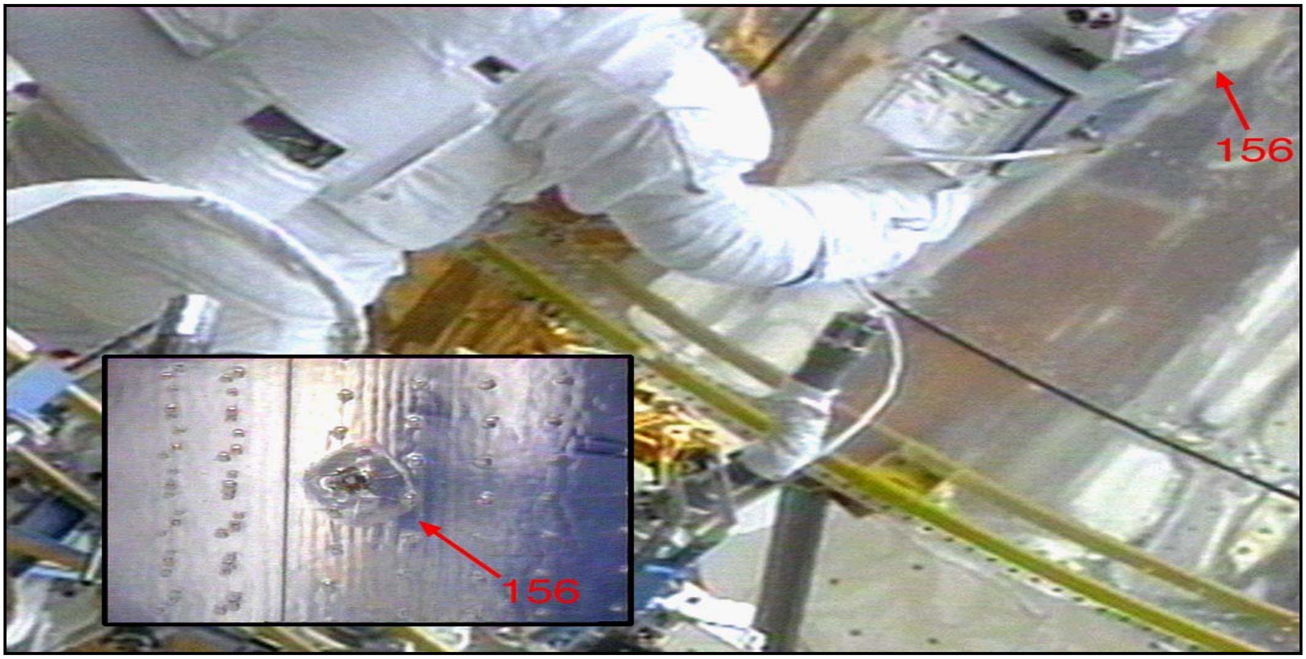


Figure 2. EVA Camera Image of MMOD Strike on -V2 Aft Shroud Door

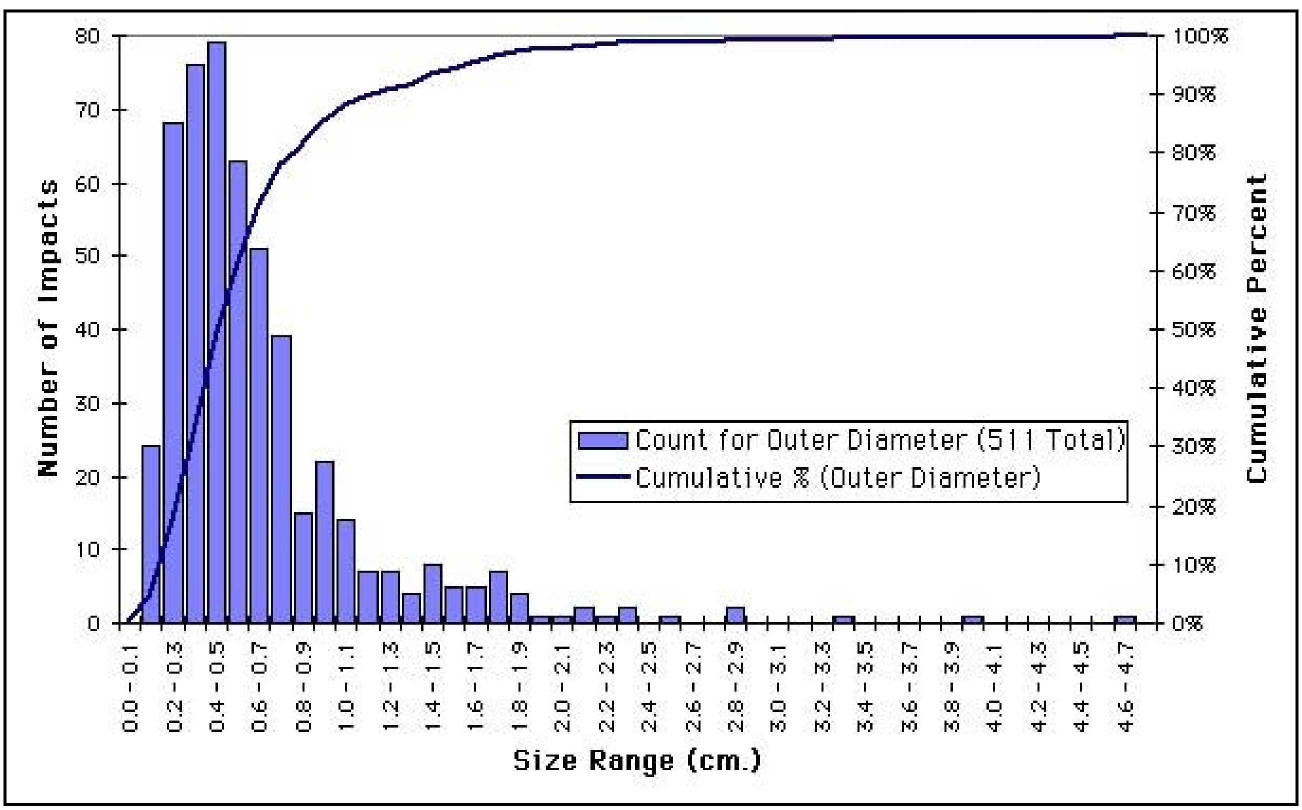


Figure 3. Size Distribution of Impact Primary Outer Diameters

NEWS, Continued

Solitary Breakup and Anomalous Events in Third Quarter are Familiar

During July and August Naval Space Operations Center personnel identified one satellite breakup and found evidence of three anomalous events. The breakup was discovered on 3 August when more than 110 debris from a Proton fourth stage ullage motor (Russian designation SOZ) penetrated the Navy's electronic fence which spans the southern United States. Launched in conjunction with a GLONASS high altitude mission on 10 January 1989, the unit (Satellite Number 19755, International Designator 1989-001G) was in an orbit of 340 km by 19,055 km with an inclination of 64.9 degrees at the time of the event. This was the 17th known breakup of a Proton SOZ ullage motor since the first one exploded in 1984.

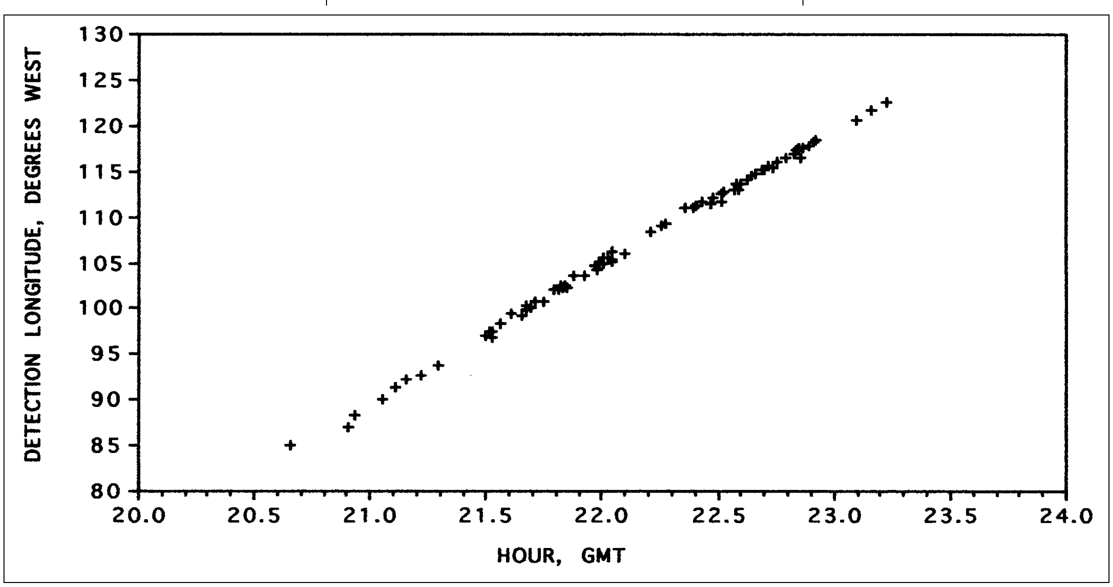
Debris detections began late on 3 August and continued steadily for over two hours. The figure below identifies 81 objects believed associated with this event. The change in longitude simply corresponds to the rotation of the Earth as the debris plane passes through the wide sensor fence. The quick spread of the debris along the orbit plane was made possible by the large semi-major axis. Orbital period differences of as much as 45 minutes were possible with less than 200 m/s ejection velocity. Thus, after a very short time posigrade and retrograde pieces could easily be hours apart. Within a week preliminary element sets had been generated on 40 objects, but none had been officially cataloged.

This ullage motor had been in orbit for 9 years and 7 months before the event, a record period of dormancy for this object class. In fact, the last four such breakups (one in 1996, one in 1997, and two in 1998) had been in orbit longer than any of their fragmenting predecessors with an average age of 9.0 years compared to the 3.6 year average for the earlier 13 breakups. No Proton ullage motor breakups have yet been identified with missions flown after 1994. A total of 73 intact ullage motors (60 from 1994 or earlier) were still in orbit during July. In addition, despite the fact that two ullage motors are released on each mission, no two of the 17 breakups to date have involved motors from the same flight, possibly suggesting a difference in design or operation.

Three anomalous events associated with old resident space objects were also noted during the quarter. A fragment (Satellite Number 4869, International Designator 1970-025EZ) associated with the 1970 Nimbus 4 upper stage breakup apparently broke into two pieces on 2 July. This object had previously shed fragments on two different occasions in 1995. The orbit at the time of the event was approximately 535 km by 650 km with an inclination of 100 degrees. Since 1985 at least three other debris from the original breakup have also fragmented with multiple new debris being produced each time.

On 1 August the PARCS radar in North Dakota detected a new piece of debris which apparently originated from the old U.S. SEASAT spacecraft (Satellite Number 10967, International Designator 1978-064A). Since 1983 SEASAT, which is currently in a nearly circular 765 km orbit with an inclination of 108 degrees, had previously spawned eight cataloged debris on various occasions with only three still remaining in orbit.

Finally, a 17-year-old Soviet rocket body (Satellite Number 12519, International Designator 1981-054E) may have shed a piece of debris in late July. The Molniya upper stage was in a highly elliptical orbit with a perigee below 100 km and an inclination of 62 degrees. The very low perigee suggests that the piece separation may have been induced by aerodynamic stresses. An element set was created on the new piece, but the object may have decayed rapidly. ❖



Detections of debris from Satellite No. 19755 by Naval radar surveillance system, 3 August 1998.

News, Continued

New Report on Historical Satellite Fragmentations

The 11th edition of the *History of On-Orbit Satellite Fragmentations* (JSC-28383) was released in August. The cut-off date for events was June 30, 1998. This is the 1st edition compiled and published by the Orbital Debris Program Office at the NASA JSC, with support from Lockheed Martin Space Mission Systems and Services. Previous editions were prepared by Teledyne Brown Engineering (TBE), under the sponsorship of the NASA JSC.

This document, often used by orbital debris modelers as a database and reference, now contains information on 152 known breakups and 33 anomalous events. Debris from these 152 events accounts for 41% of the total cataloged on-orbit Earth satellite population of 8575 objects. Just 10 of more than 3900 Space missions flown since 1957 are responsible for 25% of all cataloged artificial Earth satellites presently in orbit (Figure 1). Moreover, the sources of 9 of these 10 fragmentations were discarded rocket bodies which had operated as designed but later broke-up. Rocket bodies are the primary sources for debris in orbit today. This and other information can be found in the new edition which is now available to the orbital debris community.

The current authors would also like to thank the authors of the previous editions of this document for making their input data available. In addition, the assistance of personnel of U.S. Space Command, Air Force Space Command, Naval Space Command, and Teledyne Brown Engineering has been vital to the present work. ❖

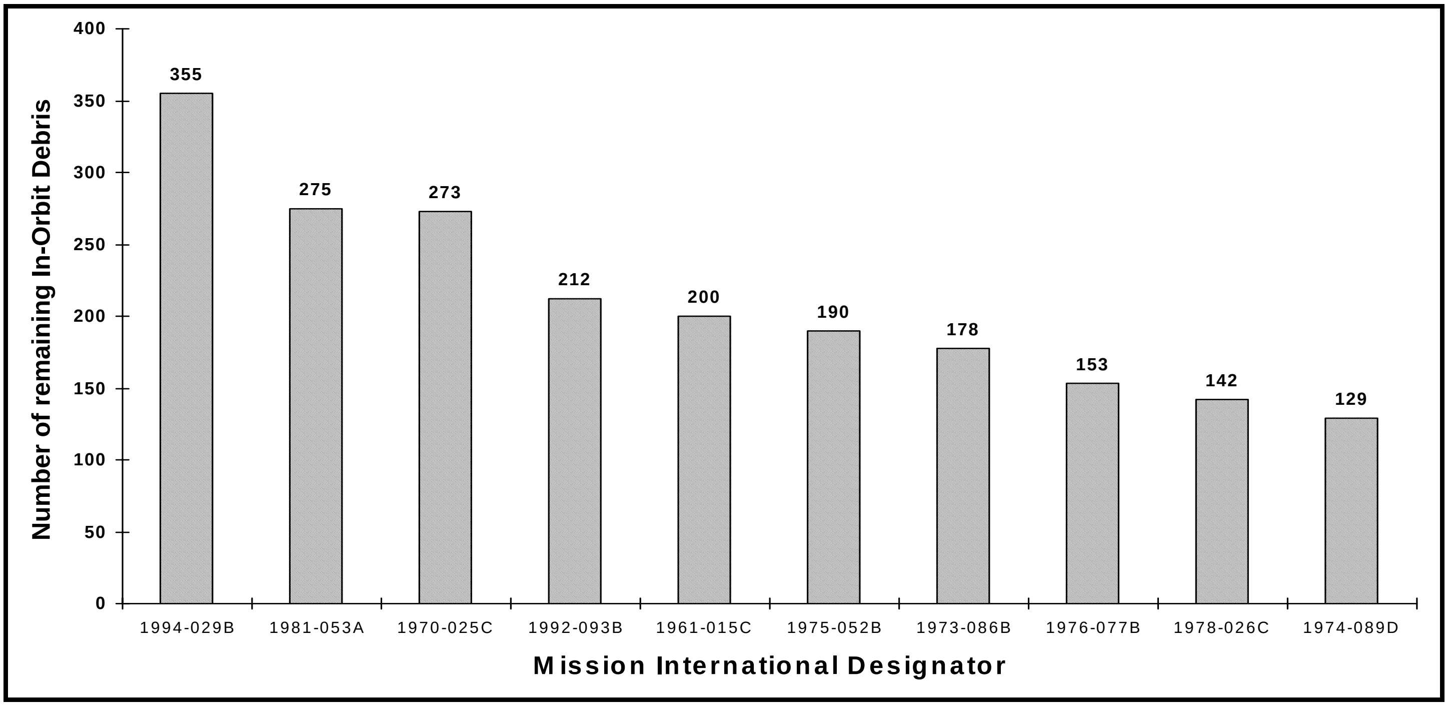


Figure 1. Magnitude of the ten largest debris clouds *in orbit* as of June 30, 1998.

The Reentry of Potential Risk Objects

In 1997 the Inter-Agency Space Debris Coordination Committee (IADC) adopted an action item to establish an informational network for the timely exchange of data on the orbital parameters and impact predictions for space objects assessed to pose potential risks to people or property. Risk objects were defined as man-made vehicles with a mass in excess of five metric tons or which contain hazardous materials. The reentry of such objects is rare, e. g., the US Skylab space station in 1979 and the Soviet Salyut 7-Kosmos 1686 space station in 1991, but the possibility of debris surviving reentry warrants special international attention.

In September 1998 the main node for this new communications network, located at ESA's European Space Operations Center, was tested and accepted. The first exercise of the system was scheduled for the second half of October on an object of opportunity, the small Inspektor spacecraft. The results of the exercise will be discussed at the 16th meeting of the IADC in early November.

The largest object currently in Earth orbit is the Mir space station with a mass of more than 120 metric tons without crew and cargo resupply vehicles. Russian officials have announced their intention to deorbit Mir in a controlled manner on 8 June 1999. Plans call for targeting any debris which might survive reentry into a region in the Pacific Ocean. A special US-Russian working group has recently been established to coordinate efforts on reentry planning and monitoring. ❖

Project Reviews

Post-flight Examination of the STS-87 Orbiter

During November-December 1997, the Space Shuttle Columbia spent nearly 16 days in a low altitude (285 km), low inclination (28.5 deg) orbit for the fourth U.S. Microgravity Payload mission. In August 1998 a report sponsored by the NASA Orbital Debris Program Office summarized the orbital debris and micrometeoroid damage discovered during post-flight inspections (*STS-87 Meteoroid/ Orbital Debris Impact Damage Analysis*, JSC-28404, Justin Kerr and Ronald Bernhard).

The primary orbiter surface areas examined included the crew compartment windows (3.4 m^2), the reinforced carbon-carbon (RCC) leading edge of the wings (41 m^2), the flexible reusable surface insulation (FRSI) on the exterior of the payload bay doors (50 m^2), and the radiator panels installed on the inside of the payload bay doors (117 m^2). In all, 189 impact sites were examined by tape pull, dental mold, or wooden probe extraction techniques. Damage regions ranged from 0.125 mm to 3.25 mm in equivalent diameter.

A total of 176 window impacts were identified with the help of a new optical micrometer and fiber optic light source, but only two - both on window number 5 - were severe enough to require replacing the window. The largest window impactor was an aluminum particle estimated to have been 0.03 mm in diameter and 0.05 mm in length. Laboratory analysis permitted characterization of 52 of the impactors: 24 orbital debris and 28 meteoroids. Of the orbital debris impactors, 71% were aluminum, 21% were stainless steel, and 8% were paint.

Examinations of the radiators led to the discovery of seven impact features with a minimum 1.0 mm damage diameter. Three sites yielded sufficient residue to determine the nature of the impactor. The two largest were 0.2 and 0.5 mm meteoroids, and the third was a 0.1 mm piece of stainless steel orbital debris.

Inspections of the FRSI found four impact sites greater than 1.0 mm in extent: two orbital debris, one meteoroid, and one of unknown origin. All three identified particles were estimated to have been 0.4-0.5 mm in diameter. Two impact sites were also found on a single RCC panel, one caused by a 0.3 mm stainless steel particle and the other caused by an unknown impactor.

Post-flight inspections of Space Shuttle orbiters continue to produce valuable data on the natural and artificial particulate environment in low Earth orbit. A new, more comprehensive assessment of these mission data has been recently initiated at JSC with preliminary results anticipated in 1999. ❖

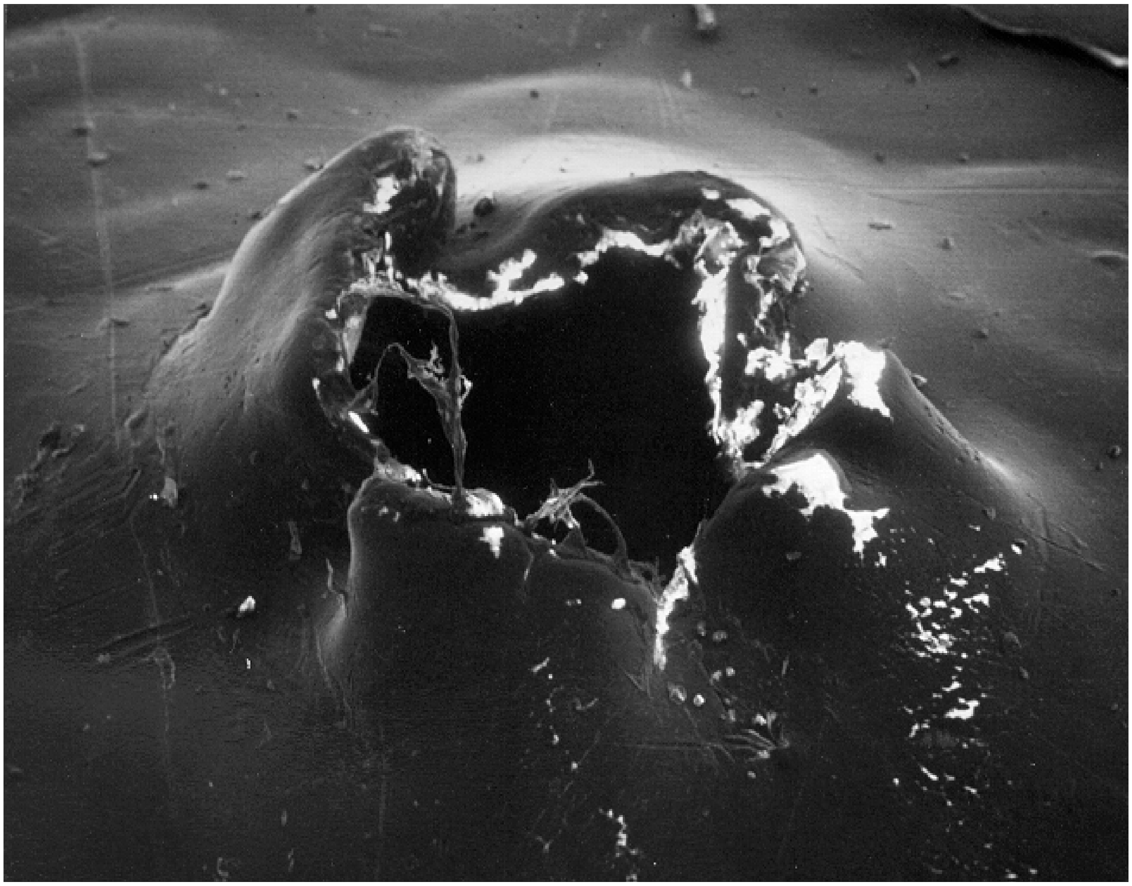
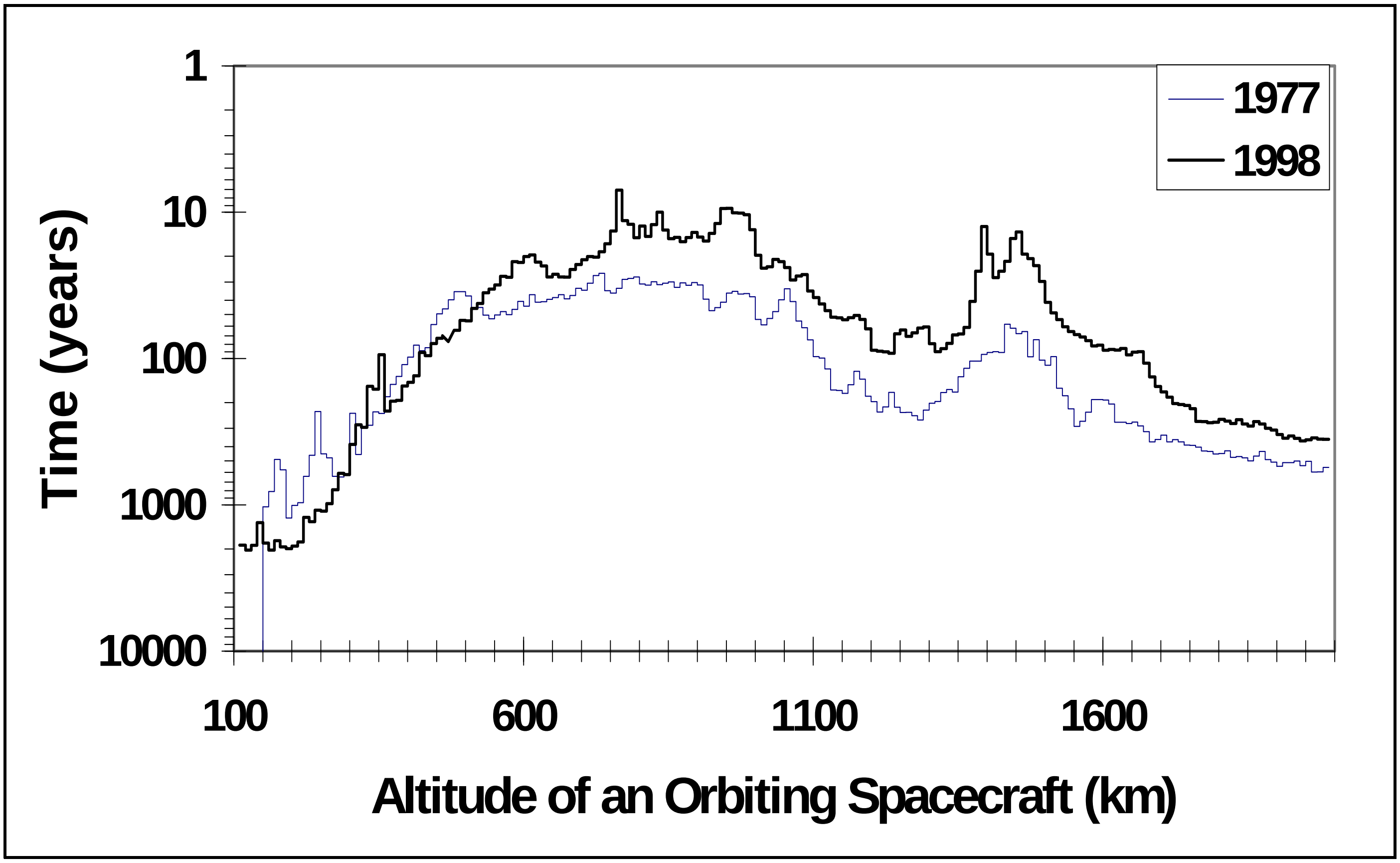


Figure 1. SEM image of a radiator impact and through face sheet penetration (sample 25).

Project Reviews



Average time that a Cataloged Object is expected to Pass within 100 Meters of an Orbiting Spacecraft - The average time is derived by computing the "collision rate" on a sphere 100 meters in diameter. This is accomplished by first calculating the average spatial density of the total catalog population. The average spatial density is computed by calculating the fraction of the time each cataloged object spends in concentric spherical shells about the Earth. Next the flux is computed by using the average spatial density of the cataloged population multiplied by the average collision velocity. This average flux is a good approximation for spacecraft in a variety of orbital inclinations. The average time between conjunctions is the area of the 100-meter diameter sphere divided by the flux at that altitude.

As can be seen from the graph, there has been an increase in the cataloged flux at altitudes above about 600-km altitude between 1977 and 1998, but below about 600-km altitude the flux has not changed significantly. Above about 600 km, the production rate of cataloged objects from launches and breakups exceeds the loss rate due to atmospheric drag. Thus the flux continues to grow at these altitudes with continued launches. Below about 600 km, the loss rate due to atmospheric drag dominates the orbit evolution. Consequently, variations in the atmospheric density due to changes in solar activity determine how quickly objects drag down from higher altitudes and control the spatial density of objects at these lower altitudes. At the lowest altitudes spatial densities are determined by fewer objects and, thus, are subject to greater variations. ❖

Breakup Model Update: Part II, Delta Velocity Distribution

This article continues the discussion from a previous issue of *Orbital Debris Quarterly News* (Volume 3, Issue 2) regarding the new NASA satellite breakup model. The first article discussed the determination of the area-to-mass (A/M) ratio for breakup fragments. To establish the initial orbits of fragmentation debris and to propagate those orbits in the EVOLVE long-term environmental model, ejection velocities must be added to the velocity of the parent satellite at the time and location of the breakup. NASA's earlier breakup models had applied a simple velocity distribution increment as a function of the mass of the debris. However, for both tracked debris and debris observed in ground tests, a more complex distribution of velocities for a given size fragment was evident. The present article describes the development of a new ejection velocity distribution model for fragmentation debris.

Using historical data from the 13 satellite breakups identified in the previous article, as well as the cataloged debris from the Fengyun 1-2 upper stage, ejection velocities for most cataloged fragments were calculated. This process involved selecting the earliest known valid element set for a specified piece of debris, propagating the orbit back to the time of the event with the earlier established A/M, and then subtracting the propagated velocity from the pre-breakup velocity. A set of velocities, as a function of both A/M and characteristic length, for debris created in a single breakup was thus

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Project Reviews, Continued

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determined.

To ensure that no significant biases were introduced during the back-propagation process, particularly for debris which were cataloged weeks or even months after the event, a test procedure was established. Ejection velocities were calculated for single debris objects using element sets of various ages, up to a year after the breakup. The differences in the assessed ejection velocities were found to be small.

For debris smaller than the cataloged population, i.e., smaller than 10 cm, ground test data from both explosions and collisions were utilized. The results were then combined with the larger debris to form smooth distributions. As expected, the velocity distributions (explosions in Figure 1 and collisions in Figure 2) were Gaussian in nature with the peak value increasing with large A/M values. In general, the velocity distributions for explosion debris were more tightly grouped than for collisions over the A/M range of 0.01 to 1.0 m^2/kg. However, the maximum velocity of small collision fragments was found to be greater than for explosion debris. No significant differences were found between spacecraft and upper stages of the same type of breakup (explosions and collisions).

The implementation of these higher fidelity velocity distributions into the new NASA breakup model will enable EVOLVE to emulate better representative debris clouds. In conjunction with the new A/M distributions, the propagation of debris from breakups should also follow more closely actual orbital decay processes. This will permit an improved understanding of the long-term effects of satellite breakups on the near-Earth environment. ❖

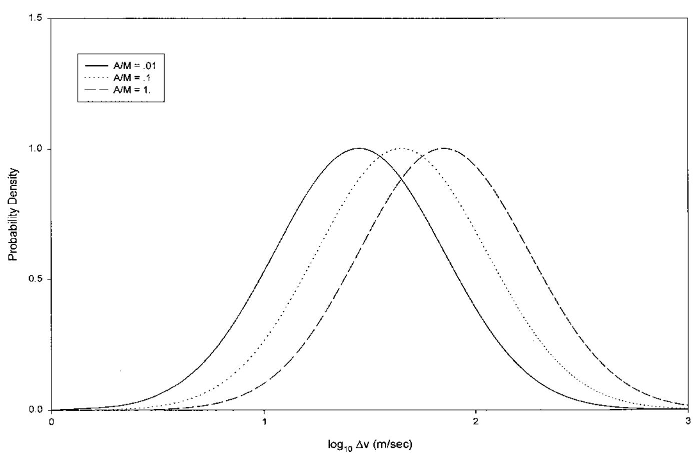

Figure 1. Distribution Function for Δv for Explosions (A/M in m^2 /kg)

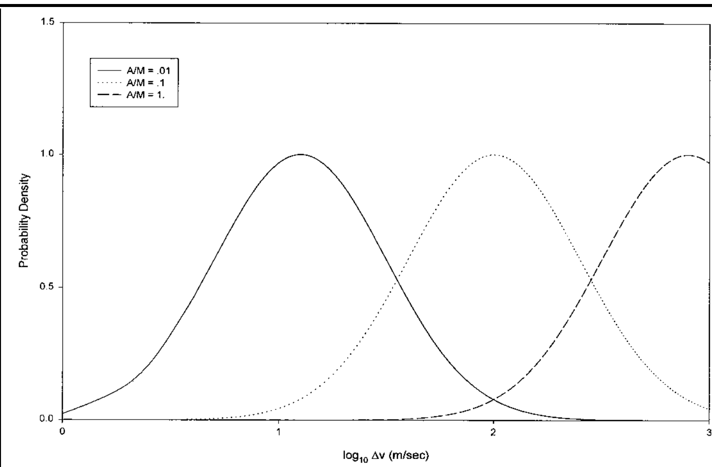

Figure 2. Distribution Function for Δv for Collisions (A/M in m^2 /kg)

Abstracts From Papers

Meteoroid and Orbital Debris Protection: Achievable Protection Levels for Space Stations in LEO

J. Theall, E. Christiansen, N. Johnson, R. Graves, J. Williamsen

Damage to long-duration space stations in Low Earth Orbit (LEO) from meteoroid and orbital debris (M/OD) impacts is inevitable. This paper, using the International Space Station (ISS) as an example, examines three questions related to this damage: (1) what protection levels can a space station afford its crew, (2) what steps can be taken during the design and planning phase of a program to mitigate the effects of this damage, and (3) is it infeasible to operate space stations in excess of a certain lifetime? Starting with ORDEM96, NASA's orbital debris environment model, and the ISS physical configuration, Probabilities of No Impact (PNI) for selected particle sizes are computed using the BUMPER code. Comparisons of general shield designs, such as the Whipple and multi-shock designs, that are capable of stopping the selected particle sizes, are made. Then Probability of No Critical Failure (PNCF) criteria based on reasonable operating assumptions with respect to station internal configuration are used to reach a final risk estimate for the crew. The effects on space station M/OD protection by visiting vehicles and space station growth are also quantified, as is the contribution to protection afforded by collision avoidance procedures. ❖

The Complexities and Challenges of Space Traffic

Nicholas L. Johnson

Mid-term and long-term projections of the Earth's satellite population rely, in part, on the ability to predict the nature and magnitude of space launch activities. Historically, the success of space traffic modeling has been a function of the degree of fidelity employed, political-economic factors, and the effects of

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Abstracts From Papers

The Complexities and Challenges of Space Traffic Modeling, Continued

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emerging technologies. This paper describes the results of space traffic modeling performed at NASA Johnson Space Center in 1998, using the author's 1986 and 1993 space traffic modeling efforts as a foundation. Despite the significant decline in world-wide space missions in the 1990's, the growth of on-orbit mass has remained essentially unchanged. The sharp decline in LEO missions by the Russian Federation has had relatively little impact on the environment since these flights primarily were inserted into orbits with short orbital lifetimes. However, the advent of the new commercial communications networks should reverse the launch decline, as evidenced by the world launch rate in 1997. At higher altitudes, the use of multiple payload launch vehicles and the reduction in the use of upper stages as a result of more spacecraft with integrated propulsion systems have also changed the calculus of earlier space traffic models. The adoption of guidelines to limit LEO spacecraft and upper stages to less than 25 years after mission completion may have a demonstrable effect on space traffic modeling, since some upper stages are being deorbited immediately after payload deployment. Finally, the potential development of new, reusable space transportation may have off-setting benefits for satellite population growth, while the emergence of new conventional launch vehicles by additional entrants in space transportation activities may be important. ❖

Breakup Model Update at NASA/JSC

A. Bade, A. Jackson, R. Reynolds, P. Eichler, P. Krisko, M. Matney, P. Anz-Meador, N. Johnson

The population in orbit can be divided into 2 major components: intact payloads and debris. The majority of objects is debris generated by different mechanisms: operational procedures, surface degradation and fragmentations. Spent intact rocket bodies and payloads are also considered as debris. Orbital debris is of importance since it is a threat to all space missions and operational payloads, including the planned International Space Station and Shuttle missions. Orbital debris is uncontrolled and can only be measured and tracked to a limited extent - insufficient for risk analyses and predictions. Therefore verified and continuously updated models are needed. This paper concentrates on first results from an ongoing project at the NASA Johnson Space Center: a major update of the fragmentation debris model. Fragmentations are the primary source for debris which are too large to be shielded against. At the same time only a small percentage of the fragments are big enough to be tracked. Therefore special attention has to be paid at the modeling of this debris source. The last major update was performed in 1989, prior to the last solar cycle. Now a longer history can be analyzed. Since 1989 also more data on tests have become available, such as velocity information from the Satellite Orbital Debris Characterization Impact Test (SOCIT). It is shown what conclusions can be drawn from the analyses of these data in terms of the basic breakup model components such as area-to-mass distribution, mass distribution and velocity distribution. ❖

Historical Evolution and Current Status of the Number and Mass of Objects in Earth Orbit

P. Eichler, R. Reynolds, A. Bade, N. Johnson

A basic requirement for the evaluation of the collision risk posed to other spacecraft by Orbital debris is the accurate assessment of the number of objects of a given mass or size as a function of altitude and inclination. For the objects above roughly 10 to 20 cm in diameter reliable data on the orbital parameters is available from the USSPACECOM measurements. Data on the sizes and masses of these objects have to be added from various literature sources describing the intact population (payloads, rocket bodies, and operational debris objects) and from breakup modeling results or RCS measurements for breakup fragments.

While the collision risk is currently dominated by explosion fragments below 10 cm diameter, reliable data on the mass of the larger objects such as payloads and rocket bodies is of special importance for calculating the number of fragments generated when an object suffers a breakup. Especially for long term environment projections and environment stability/critical density analysis, where collisions among large objects in Earth orbit play a dominant role, the reliable assessment of the sizes and masses of the larger object population is essential.

In this paper we present the historical evolution and the current number and mass of objects in Earth orbit cataloged by USSPACECOM as of January 1, 1998, broken down by object type (payloads, rocket bodies, operational debris objects, and breakup fragments) and orbit type (LEO, MEO, GTO, Molniya, and GEO). Problems which may occur in the interpretation of the USSPACECOM data such as completeness, limiting detection size, late cataloging, and objects in the 80,000-series are discussed.

Important trends in launch rate, number of objects, and mass accumulation in the different orbit types are presented. It is shown that the accumulation of mass in orbits with long lifetimes is not slowing down, despite the fact that the overall launch rate has dropped significantly over the past 7 years from an average of 116 launches per year (maximum 129, minimum 101) between 1965 and 1990 to only 73 launches in 1996. In 1997 the launch rate rebounded to 86 launches, mainly due to the beginning deployment of LEO telecommunications constellations (IRIDIUM and ORBCOMM). The total mass in Earth orbit is still growing by an average of about 160 metric tons/year over the past 20 years. One can even identify a steady increase in accumulation of mass in orbit from about 100 metric tons/year between 1966 and 1976 to about 135 metric tons/year between 1976 and 1986 to about 180 metric tons/year between 1986 and 1996. Special emphasis is given to the number and mass of objects in LEO, and the impact of the planed LEO telecommunications constellations. ❖

A Comparison of Statistical Measurements of the Orbital Debris Environment Using Radars

E. Stansbery and T.Settecerri

The U.S. Space Command maintains a deterministic catalog of orbiting satellites and debris which dates back to the beginning of the Space Age. However, the sensors and techniques used to create and maintain the catalog limit the size of the tracked objects to sizes larger than about 20 cm diameter. In order to understand the orbital debris environment for sizes smaller than this, statistical sampling has been used. NASA has been using the Haystack radar to statistically monitor the orbital debris environment since 1990. The Haystack measurements have been NASA's primary source of data in the important 0.5-20 cm diameter size range.

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INTERNATIONAL SPACE MISSIONS
July - September 1998

International Designator	Payloads	Country/ Organization	Perigee (KM)	Apogee (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
1998-040A	MOLNIYA	RUSSIA	549	39802	62.9	2	2
1998-041A	PLANET B	JAPAN	703	489381	27.3	2	2
1998-042A	TUBSAT N	GERMANY	401	769	78.9	1	2
1998-042B	TUBSAT N1	GERMANY	400	759	78.9		
1998-043A	RESURS	RUSSIA	816	819	98.8	1	3
1998-043B	FASAT B	CHILE	815	820	98.8		
1998-043C	TMSAT	THAILAND	816	819	98.8		
1998-043D	TECHSAT	ISRAEL	816	820	98.8		
1998-043E	WESTPAC	AUSTRALIA	814	820	98.8		
1998-043F	SAFIR 2	GERMANY	815	818	98.8		
1998-044A	SINOSAT 1	CHINA	35776	35798	0.1	1	0
1998-045A	COSMOS	RUSSIA	845	857	71.0	1	4
1998-046A	ORBCOMM	USA	810	828	45.0	2	1
1998-046B	ORBCOMM	USA	811	827	45.0		
1998-046C	ORBCOMM	USA	813	826	45.0		
1998-046D	ORBCOMM	USA	814	826	45.0		
1998-046E	ORBCOMM	USA	816	825	45.0		
1998-046F	ORBCOMM	USA	815	828	45.0		
1998-046G	ORBCOMM	USA	815	828	45.0		
1998-046H	ORBCOMM	USA	815	829	45.0		
1998-047A	SOYUZ TM-	RUSSIA	358	369	51.7	1	0
1998-048A	IRIDIUM 03	USA	776	780	86.4	2	4
1998-048B	IRIDIUM 76	USA	776	780	86.4		
1998-049A	ST-1	TAIWAN	35755	35817	0.0	1	0
1998-050A	ASTRA 2A	LUXEMBOURG	35743	35788	0.1	2	2
1998-051A	IRIDIUM 82	USA	702	706	86.5	1	0
1998-051B	IRIDIUM 81	USA	776	779	86.4		
1998-051C	IRIDIUM 80	USA	777	779	86.4		
1998-051D	IRIDIUM 79	USA	499	549	86.0		
1998-051E	IRIDIUM 77	USA	703	708	86.5		
1998-052A	PAS 7	USA	35776	35897	0.1	1	0
1998-053A	ORBCOMM	USA	812	821	45.0	2	0
1998-053B	ORBCOMM	USA	806	828	45.0		
1998-053C	ORBCOMM	USA	812	821	45.0		
1998-053D	ORBCOMM	USA	811	821	45.0		
1998-053E	ORBCOMM	USA	808	819	45.0		
1998-053F	ORBCOMM	USA	809	819	45.0		
1998-053G	ORBCOMM	USA	809	819	45.0		
1998-053H	ORBCOMM	USA	810	820	45.0		
1998-054A	MOLNIYA	RUSSIA	421	40657	62.8	2	1

Upcoming Meetings

3-6 November 1998: *The 16th Inter-Agency Space Debris Coordination Committee* (IADC) meeting, Toulouse, France, hosted by CNES.

16-20 November 1998: *Hypervelocity Impact Symposium 1998*, Von Braun Center, Huntsville, Alabama. Website: http://www.futureonline.com/hvis/

7-10 February 1999: *9th AAS/AIAA Spaceflight Mechanics Conference* (Space Debris session), Beaver Run Resort, Breckenridge, Colorado. Website: http://www.astronautical.org

22-26 February 1999: *Meeting of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space*, United Nations, Vienna, Austria.

May 1999: *UN Conference on Near-Earth Space* (Space Debris session), United Nations and the New York Academy of Sciences, New York, New York. Contact Dr. John Remo email jlremo@cfa.harvard.edu

Next Issue

- **New results from NASA's Liquid Mirror Telescope and CCD Debris Telescope**
- **Orbital debris and meteoroid risk assessments for the International Space Station**

ORBITAL BOX SCORE

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

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	24	100	124
CIS	1337	2586	3923
ESA	23	204	227
INDIA	17	4	21
JAPAN	65	51	116
US	812	3162	3974
OTHER	258	25	283
TOTAL	2536	6132	8668

Abstracts From Papers

A Comparison of Statistical Measurements of the Orbital Debris Environment Using Radars

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Although the Haystack data comprise the largest database of observations, other radars have also been used to statistically sample the debris environment. The Haystack Auxiliary (HAX) radar, co-located with Haystack, began collecting debris data in 1994. By sharing location, real-time data collection hardware and software, and post-mission data analysis, any differences in results should be attributable to wavelength effects. The Goldstone radar is slightly more sensitive than Haystack and actually began sampling the debris environment in 1989, although for only a few hours each year. In 1996, a radar measurement campaign coordinated by the Inter-Agency Space Debris Coordination Committee (IADC) was conducted using Haystack, the FGAN/TIRA radar operated in a bi-static mode with the Effelsberg radio telescope, and the TRADEX radars. During this campaign each radar collected approximately 24 hours of statistical debris data. Limited data are also avalable from older statistical measurements from the Arecibo and ALTAIR radars. This paper compares the results of these different measurements and attempts to reconcile any observed differences. ❖

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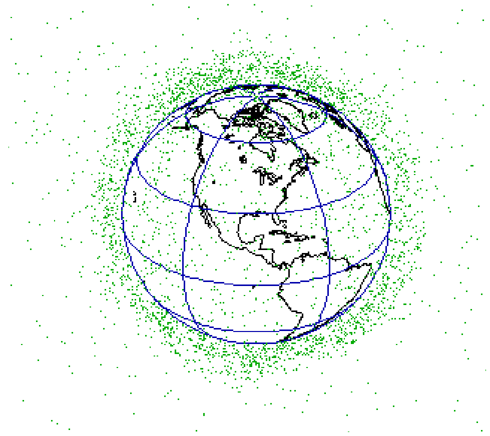

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