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NEWS

Release of ORDEM2000

J.-C. Liou

The new orbital debris engineering model ORDEM2000 was released by the NASA Orbital Debris Program Office earlier this year. The model is appropriate for engineering solutions requiring knowledge and estimate of the orbital debris environment (spatial density, flux, *etc.*) in the low Earth orbit region between 200 and 2000 km altitude. It can also be used as a benchmark for ground-based debris measurements and observations.

The highlights of the new model include: (1) a large set of observational data (both *in-situ* and ground-based), covering the object size range from 10 μm to 10 m, was incorporated into the ORDEM2000 debris database, (2) a new analytical technique was employed to convert observational data into debris population probability distribution functions - these functions then form the basis of debris populations, and (3) a finite element model was developed to process the debris populations to form the debris environment. In addition, a more capable input and output structure and a user-friendly Graphical User Interface (GUI) are also implemented in the model.

ORDEM2000 has been subjected to a significant verification and validation effort. The new model has been tested thoroughly and compared with all available data. Overall, it provides a very good description of the current debris environment. The model is now being used for Space Shuttle and International Space Station for debris risk assessments. ORDEM2000 is available at the Orbital Debris Program Office website at http://sn-callisto.jsc.nasa.gov/model/modeling.html. v

The Leonid Storm of 2001

B. Cooke

On the night of November 17-18 of this past year, the Leonid meteor shower reached storm level activity over the United States for the first time since 1966. To most, Mother Nature treated them to a spectacular sky show, with meteors appearing every few seconds at the first maximum near 10:30 UT (04:30 CST). To those of us involved in the forecasting and observing of the Leonids, the 2001 storm proved to be a strange mix of excitement and disappointment… It was exciting in that the forecasts proved to be reasonably accurate in terms of the level and duration of the activity and that, of the 6 observation sites manned by MSFC and University of Western Ontario personnel (Eglin AFB, Huntsville, Apache Point, Haleakala, Guam, and Ulan Baator, Mongolia), only Guam experienced cloudy weather, enabling the collection of data over the entire duration of the storm. The disappointment came from the realizations that all of the forecasts were wrong in some details (mine and Peter Brown's apparently fared the worst), and that a fair amount of work would be needed to locate manpower and funds to reduce the 2+ terabytes of

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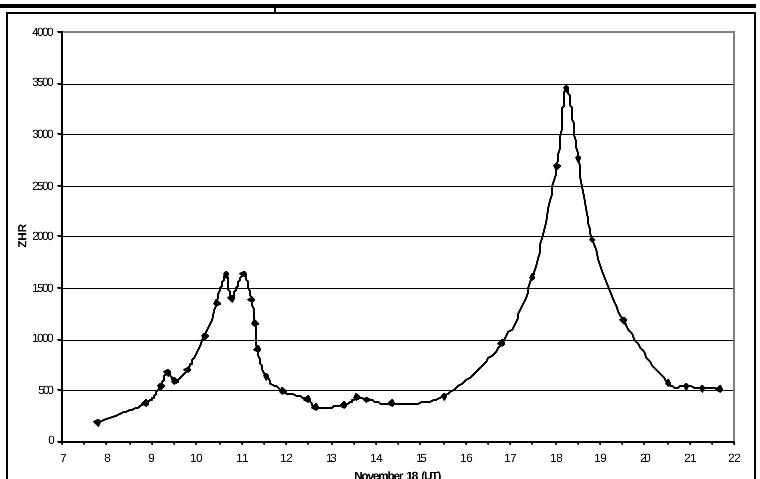

Figure 1. 2001 Leonid ZHR profile (IMO, January 2002).

Inside...

NEWS

The Leonid Storm of 2001, Continued

(Continued from page 1)

video data collected by the observing teams.

As depicted in figure 1, the 2001 Leonids had two major peaks; the first, mentioned above, reached a maximum Zenith Hourly Rate (ZHR) of around 1600 at 10:35 UT. According to the International Meteor Organization, it is bimodal in nature, with a secondary peak some 24 minutes later, at approximately the same level. The second and larger peak occurred over Asia, at approximately 18:15 UT. It reached a ZHR of 3400, close to the level of the 1999 storm, which peaked at 3700 Leonids per hour. However, unlike the brief outburst of 1999, the 2001 Leonids exhibited significantly elevated activity (ZHRs > 300) for over 12 hours, resulting in a much greater fluence; a current estimate would place it at approximately 4.5 times that of 1999, or about 7 Leonids km^{-2} down to mass of approximately 10 µg. This is in good agreement with the forecast fluence levels of 5 to 10 Leonids km^{-2}. It is somewhat ironic that satellite operators devoted much more attention to the 1999 shower than the 2001 apparition, where the risk was roughly 5 times greater.

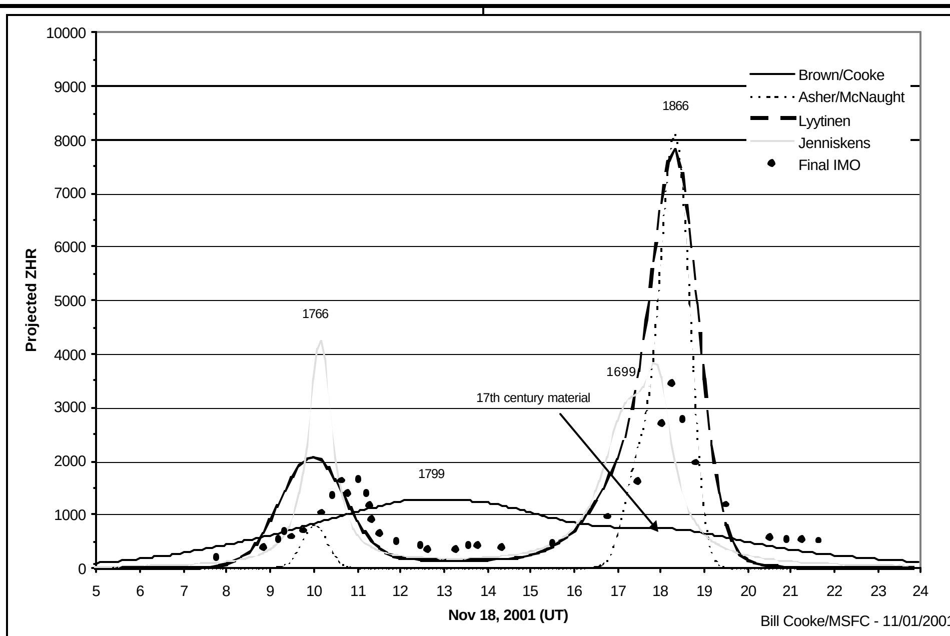

Figure 2. 2001 Leonid forecasts.

While the forecasts did a good job of characterizing the length and overall characteristics of the 2001 Leonids, they fail in the "fine" details. In particular, forecasting the level of the maxima remains problematic, as a glance at figure 2 shows. The Brown/Cooke profile looks particularly disconcordant; this is due to the dynamical model placing the 1799 stream closer to Earth, resulting in the peak at 13:00 UT, resulting in a much greater contribution to the ZHR profile. It is hoped that the forecasters will take a good look at the 2001 data and use it to revise their models, as storm level Leonid activity is once again projected for 2002. At Marshall, work is progressing in devising an automated method of reducing the video data, the results of which will be used in producing a revised 2002 Leonid forecast. ♦

Project Reviews

Reentry Survivability Analysis of the Upper Atmosphere Research Satellite (UARS)

W. C. Rochelle and J. J. Marichalar

The National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) Upper Atmosphere Research Satellite (UARS), which was launched September 12, 1991 by the Space Shuttle STS-48, will be decommissioned in 2002-2003. It is currently planed to allow the spacecraft to reenter in an orbital decay mode. In accordance with NASA Policy Directive 8710.3, GSFC performed a reentry analysis of the UARS spacecraft using the NASA Lyndon B. Johnson Space Center (JSC) Debris Assessment Software (DAS). The GSFC DAS results showed the UARS spacecraft to be non-compliant with NASA Safety Standard 1740.14 Guideline 7-1, which requires the surviving debris of an uncontrolled spacecraft reentry to produce a risk to ground population no greater than 1:10,000. In response to the results, GSFC requested an analysis be performed using the higher-fidelity Object Reentry Survival Analysis Tool (ORSAT), developed by JSC and Lockheed Martin Space Operations (LMSO).

The approximately 5670 kg UARS satellite is providing data on chemistry, dynamics, and energy balance above the Earth's troposphere and coupling between these processes and other atmosphere regions. It also measures ozone and chemical compounds that affect chemistry processes in the ozone layer. The UARS observatory consists of a standard Multi-mission Modular Spacecraft (MMS) coupled to an Instrument Module that includes ten science instruments and various mission-unique components. The starboard view of the UARS space, with the locations of some of the instruments, the MMS, and other elements, is shown in Fig. 1.

The UARS will be decommissioned upon completion of its current Science Traceability Mission. There is not enough propellant on board or the spacecraft to reenter in a targeted (controlled) entry mode. Eventually the orbital decay of the UARS spacecraft will cause it to reenter the Earth's atmosphere, resulting in break-up and demise of most of the spacecraft components. However, due to the mass, size, and material properties of some of the components, there is an increased possibility of those components surviving the atmospheric reentry and posing a safety risk to the ground population.

In the reentry analysis performed using ORSAT, entry interface for the UARS spacecraft was assumed to be 122 km, with initial break-up occurring at 78 km. This point is the

(Continued on page 3)

NEWS

Reentry Survivability Analysis of the Upper Atmosphere Research Satellite (UARS), Cont'd

(Continued from page 2)

approximate altitude at which a majority of satellites break up according to observations by Aerospace Corporation. Below this altitude, the primary components were assumed to split from the parent body and enter separately. In a number of cases, further fragmentation of subcomponents occurred.

Approximately 160 UARS components were analyzed with ORSAT including those making up the ten instruments for mapping data on the Earth's atmosphere, and those included in the MMS. Detailed component properties were obtained and used to model each individual component in ORSAT. Approximately 96 percent of the aerodynamic mass and 92 percent of the thermal mass was analyzed or accounted for. Twelve types of components (for a total of 26 objects, accounting for multiple components) were found to survive. The surviving objects included seven objects made of titanium, two of beryllium, two of stainless steel, and one very large (158 kg) object made of aluminum. Titanium, steel, and beryllium tend to have higher survival tendencies due to the high melting temperatures of these materials (1943 K, 1644K, and 1557 K, respectively).

In ORSAT a component is considered to demise once the total heat absorbed (net heating rate integrated over time, multiplied by its surface area) becomes greater that the heat of ablation of the object. With such high melting temperatures, and in the case of the aluminum object with its very high mass, the heat of ablation for these 12 objects was never reached in the ORSAT analysis, resulting in their survival.

Figure 2 shows a plot of demise altitude vs. downrange for the objects analyzed, showing the objects that survived with zero altitude. A debris footprint length of 788 km occurred, with a total survival mass of 532 kg of the 26 objects that survived. The total debris casualty area was 22.4 m^2, which corresponded to a total casualty risk of 1:3560 at the inclination angle of 57º. v

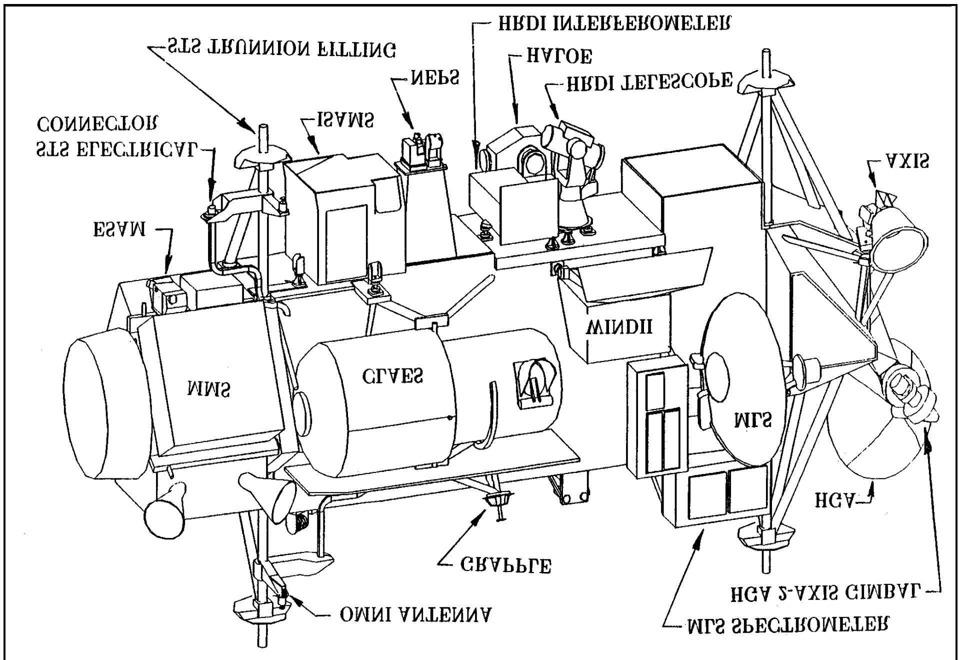

Figure 1. Starboard view of UARS showing instrument locations.

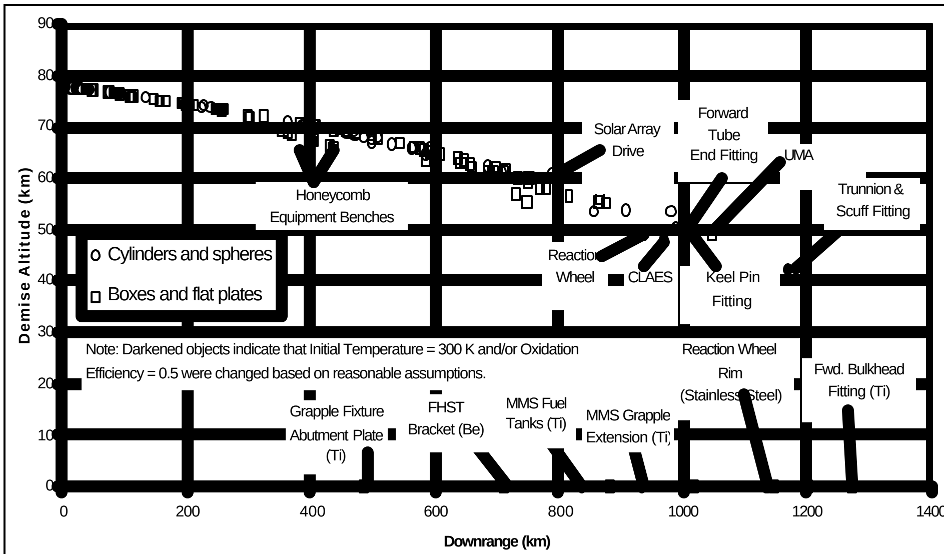

Figure 2. Demise altitude vs. downrange for UARS components

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Project Reviews

Albedo Distributions of Debris

M. Matney

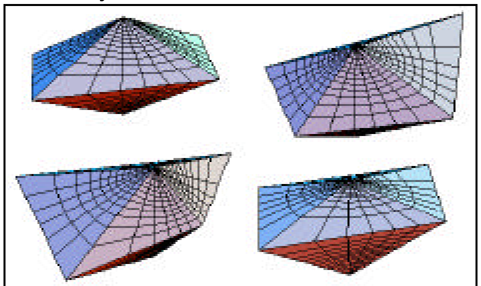


Figure 1. Examples of a 3:2:1 ratio irregular octahedron. The variation is due to sliding each axis randomly, while maintaining its length.

One of the primary goals of optical observations of the orbital debris environment is to obtain a size distribution of the debris in orbit. However, the size of an object is never measured directly, only its brightness. The relationship between the brightness of an object and its size is typically lumped into a term called the "albedo". There are many types of "albedo", but the one we seek for debris is an amalgam of the reflectivity and diffuseness of the material as well as the shape and orientation of the object. Typically, the size of an object (we use the definition of size of irregular objects used by radar measurements – the average of the three primary orthogonal lengths of the object) is defined relative to the size and brightness of an equivalent-size specular sphere. This means that if the object at certain orientations (e.g., a specular disk) is brighter than an equivalent-size sphere, its albedo can exceed a value of 1.

In an effort to understand the albedo of irregular debris, we have been using debris analogs to simulate the variability of the albedo. From work with radar, a good debris analog is the bipyramid, or orthogonal octahedron. The size of this object is simply the average of the three primary axes. A good debris analog is to let the center of each axis be randomly positioned (but still mutually orthogonal – allow each axis to be able to slide lengthwise back and forth) and use a ratio of the total axis lengths of 3:2:1. The distribution of albedo is plotted in dB space in analogy to that used in radar work. To obtain the distribution, the albedo relative to an equivalent size specular sphere is computed for many random orientations and random axis centers. This can be done for specular and diffuse surface types.

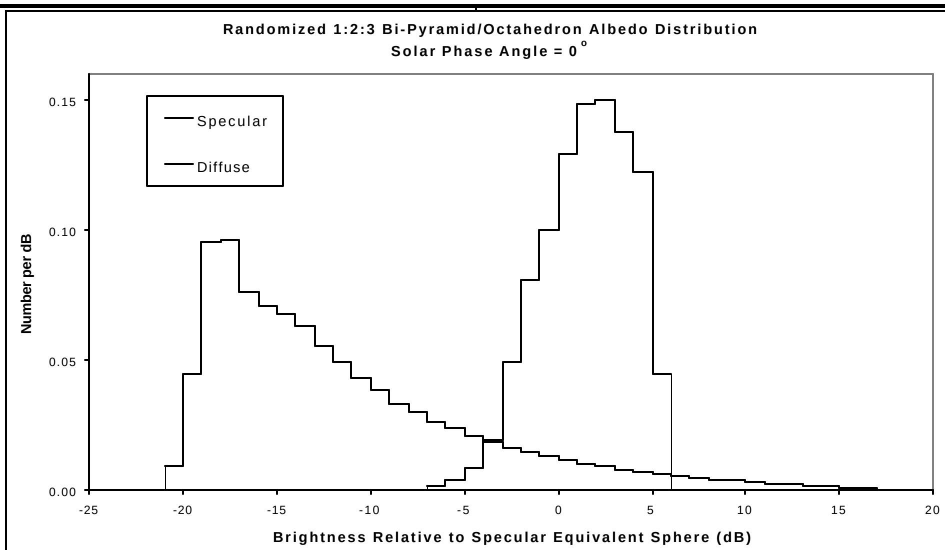


Figure 2. For a collection of octahedrons with 3:2:1 ratios and randomized axis centers (see figure 1), the brightness relative to an equivalent specular sphere can vary over an order of magnitude or more due to orientation. Note that irregular objects with specular surfaces have a wider dynamic range in albedo than those with diffuse surfaces. Solar phase angles near zero degrees are typical of GEO objects.

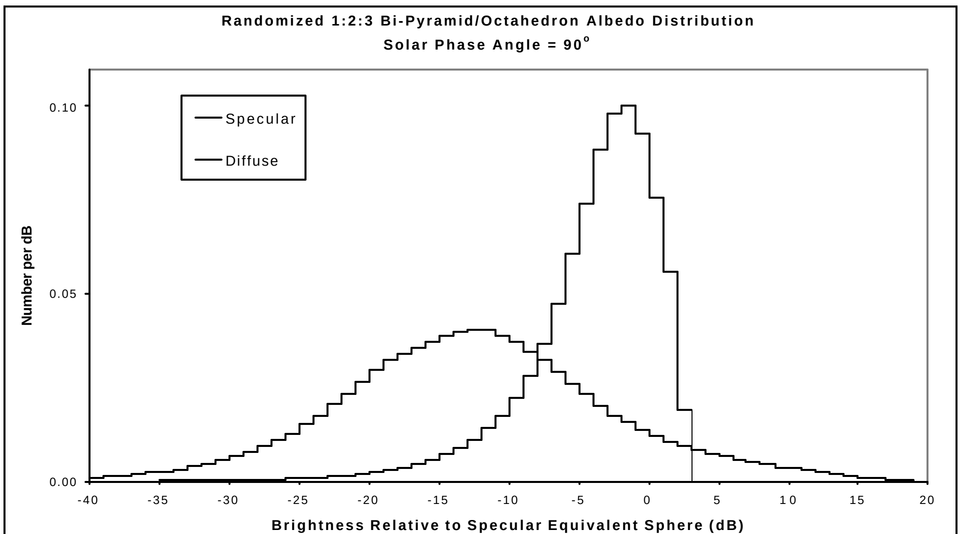


Figure 3. For a collection of octahedrons with 3:2:1 ratios and randomized axis centers (see figure 1) the brightness relative to an equivalent specular sphere can vary over an order of magnitude or more due to orientation. Solar phase angles near 90º are typical of LEO observations. For the 90º case, the specular distribution looks similar to a normal distribution. These distributions are morphologically similar to those used in radar analysis.

As can be seen from figures 2 and 3, depending on the solar phase angle and surface type, the brightness of an equivalent size object can vary up to several orders of magnitude. If the surface is not white, then there is an offset due to the true albedo of the surface, but this simply shifts the distributions shown to the left or right (for instance if the surface is black with an albedo of 0.1, the resulting distribution is shifted to the left 10 dB).

Studies are ongoing to determine what distributions are appropriate for debris objects. Once these distributions are known, it should be possible to estimate better size distributions for LEO (Low Earth Orbit) and GEO (Geosynchronous Earth Orbit) optical observations. v

Meeting Report

Annual Meeting of the NASA/DoD Orbital Debris Working Group
6 February 2002 Houston, Texas

The annual meeting of the NASA/DoD Orbital Debris Working Group was held at the NASA Johnson Space Center on 6 February. The Working Group was formed in 1997 in response to a recommendation by the White House Office of Science and Technology Policy in *Interagency Report on Orbital Debris, 1995*. This year's meeting was the fifth by the Working Group, which consists of representatives of NASA, U.S. Space Command, Air Force Space Command, Naval Space Command, Army Space Command, and other Department of Defense organizations.

The principal topic of the meeting addressed current and future space surveillance capabilities. Improvements to two large phased-array radars in Florida and Alaska are instrumental to the goal of increasing the sensitivity of the overall Space Surveillance Network (SSN) to objects as small as 5 cm in diameter. Anticipated sensor upgrades, especially to the Naval Electronic Fence, may further lower the sensitivity limit to 2 cm or less in low Earth orbit (LEO). Meanwhile, the joint NASA/DoD small debris measurement program with the Haystack and Haystack Auxiliary radars continues to yield an excellent statistical picture of the LEO debris environment below 1300 km to a sensitivity of 5 to 10 mm, depending upon altitude.

Another important topic discussed at the Working Group meeting was the collection and processing of debris data following a satellite breakup. The consequences of and the organizational responses to the significant satellite breakups of November and December 2001 (Orbital Debris Quarterly News, Vol. 7, Issue 1, January 2002) were addressed in depth. The deterministic debris data acquired by DoD for objects typically larger than 10 cm in diameter must be combined with the statistical analyses of the smaller debris population performed by NASA to develop an integrated threat assessment for both piloted and robotic spacecraft. v

39th session of the Scientific and Technical Subcommittee (STSC) of the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS)
25 February – 8 March, 2002 Vienna, Austria

The 39th session of the Scientific and Technical Subcommittee (STSC) of the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS) was held in Vienna, Austria 25 February – 8 March. During the second week of the session, the subject of orbital debris, a Subcommittee agenda item since 1994, was addressed. This year's special topic, in accordance with the multi-year work plan adopted in 2001, was the hazards and experience of hypervelocity impacts on spacecraft by small orbital debris. National presentations on orbital debris were given by France, Germany, Japan, and the United States, as well as by the European Space Agency (ESA) and the Inter-Agency Space Debris Coordination Committee (IADC). Although small orbital debris and meteoroid impacts on spacecraft occur frequently, to date with rare exceptions the consequences do not threaten the mission of the vehicle. However, as the number of larger debris in Earth orbit increases, the potential for serious damage also increases.

The 40th session of the STSC in February 2003 will address the subject of international orbital debris mitigation guidelines. At that time the IADC will present a set of consensus guidelines developed by the 11 IADC members, which include the space agencies of 10 space-faring nations and ESA. The STSC multi-year work plan envisions all STSC members agreeing to a common set of orbital debris mitigation guidelines by the 41st session in 2004. These guidelines will then be forwarded to the full COPUOS for evaluation and endorsement. v

Orbital Debris Colloquium at the Goddard Space Flight Center
20-21 March, 2002 Greenbelt, Maryland

During 20-21 March, personnel from NASA Headquarters and several NASA Centers met at the Goddard Space Flight Center to participate in an orbital debris colloquium. Following a successful colloquium held at NASA Headquarters in April 2001, this year's meeting was organized with the goal of continuing the education of the NASA community on orbital debris policy, mitigation procedures, and research activities. A second objective was to discuss plans to improve the existing NASA Policy Directive on orbital debris (NPD 8710.3) and the NASA Safety Standard on orbital debris mitigation guidelines (NSS 1740.14).

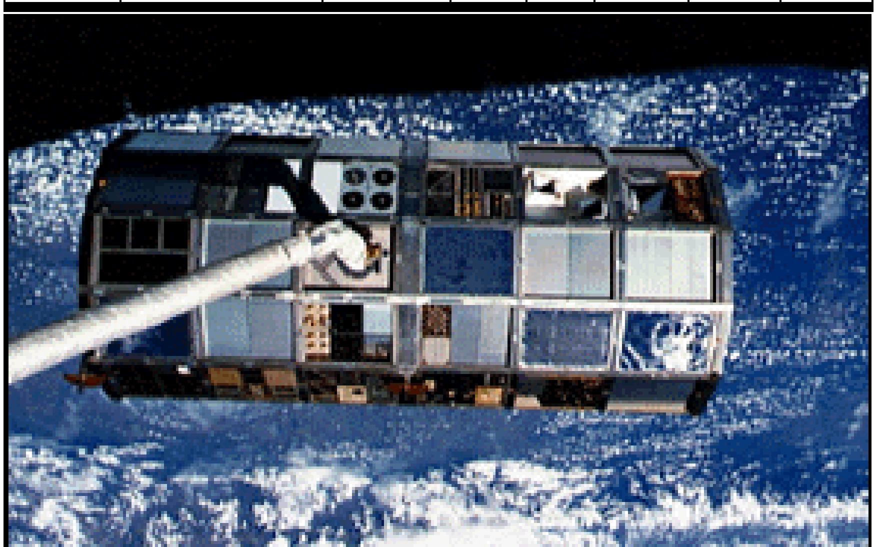
After a background on the state of the orbital debris environment and the importance of national and international orbital debris mitigation measures, proposed changes to NASA orbital debris policy and standards were presented. The primary purpose for the changes is to clarify organizational responsibilities and to take advantage of lessons learned since NSS 1740.14 was adopted in 1995. The new policy and standards will reiterate NASA's commitment to orbital debris mitigation and will improve the efficiency of their implementation.

Reports on organizational activities were made by the Johnson Space Center, Goddard Space Flight Center, Kennedy Space Center, Marshall Space Flight Center, and the Jet Propulsion Laboratory. NASA Headquarters representatives reviewed agency issues of policy and legal affairs. Several reports were given on how specific NASA programs (e.g., TRMM, Landsat 4, ERBS, GLAST, EUVE, and RXTE) had or planned to address orbital debris mitigation issues. The meeting was followed by a tutorial course on NASA's satellite reentry model, Object Reentry Survival Analysis Tool (ORSAT). v

INTERNATIONAL SPACE MISSIONS

January—March 2002

International Designator	Payloads	Country/ Organization	Perigee (KM)	Apogee (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2002-001A	USA 164	USA	NO ELEM. AVAILABLE			1	0
2002-002A	INSAT 3C	ESA	35773	35799	0.1	1	0
2002-003A	MDS 1	JAPAN	457	35710	28.4	1	0
2002-003B	DASH	JAPAN	441	35755	28.5		
2002-004A	HESSI	USA	577	604	38.0	1	0
2002-005A	IRIDIUM 90	USA	658	686	86.6	1	0
2002-005B	IRIDIUM 91	USA	662	682	86.6		
2002-005C	IRIDIUM 94	USA	665	679	86.6		
2002-005D	IRIDIUM 95	USA	663	681	86.6		
2002-005E	IRIDIUM 96	USA	663	681	86.6		
2002-006A	ECHOSTAR 7	USA	35782	35793	0.0	1	0
2002-007A	INTELSAT 904	INTELSAT	35778	35794	0.0	1	0
2002-008A	COSMOS 2387	RUSSIA	202	305	67.1	1	0
2002-009A	ENVISAT	ESA	785	791	98.6	1	0
2002-010A	STS 109	USA	486	578	28.5	0	0
2002-011A	TDRS 9	USA	EN ROUTE TO OP. ORBIT			1	0
2002-012A	GRACE 1	USA	482	506	89.0	1	0
2002-012B	GRACE 2	USA	482	507	89.0		
2002-013A	PROGRESS M1-8	RUSSIA	389	394	51.6	1	0
2002-014A	SZ-3	CHINA	332	337	42.4	1	0



Long Duration Exposure Facility (LDEF). Data from this experiment has been used to formulate orbital debris models, such as ORDEM2000.

ORBITAL BOX SCORE

(as of 27 March 2002, as catalogued by US SPACE COMMAND)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	32	305	337
CIS	1336	2507	3843
ESA	32	285	317
INDIA	22	232	254
JAPAN	71	46	117
US	966	2796	3762
OTHER	317	26	343
TOTAL	2776	6197	8973

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Upcoming Meetings

23-25 April 2002: Space Control Conference, Lexington , Massachusetts. The conference addresses a broad range of topics related to Space Control, including, but not limited to, Space Control Issues such as protection, simulation & modeling, and situational awareness; Space Surveillance Technology, both space and ground based; and Monitoring and Identification including object identification and status monitoring and satellite imaging.

10-19 October 2002: The World Space Congress 2002, Houston Texas. This is the second joint congress of COSPAR, IAC, IAF, IAA, and IISL. Several debris-related sessions, including measurements, modeling, hypervelocity impact tests, and mitigation measures and policies, have been planned. Additional information for the congress is available at www.aiaa.org/WSC2002/index.cfm.

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